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Transportation and
Communications
Minister :
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Engineering
Materials
Office

Soils and
Aggregates
Section

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Provincial Highways

Segregation Study Part II (Evaluation of Stockpile and Delivery Sampling) Granular Materials

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1. EXECUTIVE SUMMARY

Part I of this study, published as EM-70 found that for Granular A there was no significant difference between delivery and road samples. Part II was initiated to determine the relationship between stockpile and delivery samples. The projects studied in this report were carried out during the 1983 construction season. They were chosen to ensure that a sufficient quantity of material was sampled and to encompass a variety of stockpile construction procedures. The evaluation consisted of statistical testing for a significant difference between the means and variances of the random samples taken from each of the two points of sampling.

The findings indicated that in all cases where there was a significant difference in the means between stockpile and delivery samples the delivery samples showed a finer gradation than stockpile samples. The study also indicated that where there was a significant difference in variances no trend was apparent, as delivery samples had a larger variance half of the time and a smaller variance the other half.

FHWA-RD-79-100, points out that 72 percent of variance (standard deviation squared) in base course aggregates comes from the material, i.e. segregation, 15 percent comes from sampling and 13 percent

comes from testing. The source of variance in materials is from either natural variation or inadequate mixing, handling and stockpiling. Good stockpiling procedures can go a long way in reducing and minimizing these sources of variance.

Based on the conclusion of this study it is recommended that stockpile construction adhere to the requirements of subsection 1000.09.05 of MTC Form 1000 and that MTC adopt a provincially uniform stockpile sampling procedure. By implementing these changes it is believed that delivery or road samples when compared to stockpile samples will give reliable and consistent results. It is also recommended that if construction of stockpiles is carried out according to the requirements of subsection 1000.09.05 of MTC Form 1000 and subplot samples are taken using the random area method from the levelled area of the stockpile, then these samples could be used for acceptance; otherwise, samples for acceptance should be taken as the trucks are loaded from the stockpile or from the road.

One significant finding of this study was that there is excellent correlation in both accuracy and precision between field laboratories and the Head Office laboratory located in Downsview.

2. INTRODUCTION

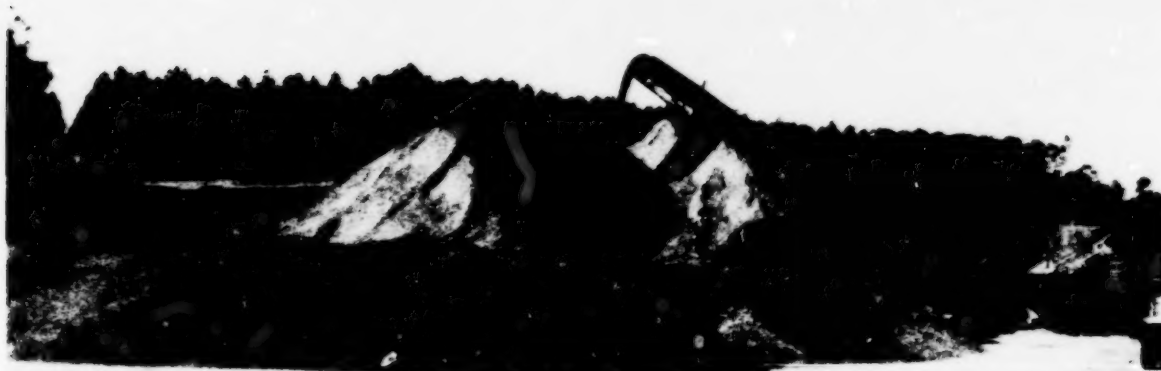
In Part I of this study, (Report EM-70), it was stated that sampling of aggregates for acceptance should be carried out as close as possible to the point-of-use. Part I also established that both delivery and road samples statistically gave the same result. At the same time, it indicated that samples taken from the stockpile gave results that were, in many cases, significantly different from delivery or road samples. Significantly different is defined as a difference in either the mean or variance of the results from the two points of sampling that is due to some cause other than chance. The magnitude of the difference is dependent on the mean, the standard deviation, and the number of samples.

If MTC adopted universal delivery or road sampling for acceptance, and the contractor or producer wished to exercise production control during stockpiling, the question arises which method of stockpiling and stockpile sampling, if any, would give results that agree with delivery or road test results.

The purpose of this portion of the study was to select sufficient contracts, analyse the results from both stockpile and delivery samples, and make recommendations as to the best method to build stockpiles and to acquire acceptance samples, so that stockpile and delivery or road samples give reliable and consistent results.

On project 1A the producer agreed to take end of belt samples for purposes of comparing them with stockpile acceptance and delivery samples. Information from two other end of belt studies are included.

This report contains the methods used, a description of eight field projects, an analysis of the results, and conclusions and recommendations.



Stockpiling of Granular A on Project 1A

3. GENERAL OUTLINE OF THE STUDY

3.1 Sampling and Testing

For statistical purposes it was desirable to have a minimum of 30 tests for each point of sampling. Contracts were, therefore, chosen to ensure a minimum of 30 000 t of Granular A as MTC testing frequency is one test per 1 000 t (i.e. 4 tests for a lot of 4 000 t). All samples were chosen randomly, and were to be taken following acceptable Ministry procedures.

All stockpile samples were taken by on site field technicians. These samples were used for contract acceptance purposes. All contracts, except two, were selected prior to or just after being awarded so that instructions could be given to the field technicians. Stockpile samples were split, with one half being used for contract acceptance, and the other for the study. All stockpile acceptance samples were tested in the field laboratories. The split portion of the acceptance sample was tested at the Head Office laboratory at Downsview. A comparison of the test results from the field and H.O. laboratories, although not an objective of the study, was carried out, and is presented in this report.

The delivery samples which had no bearing on the acceptance of Granular A, were taken either by a student technician or a senior technician from the Soils and Aggregates Section, Engineering Materials Office. These samples were taken randomly, and according to the method outlined in EM-67 (Guidelines for Acceptance Sampling and Testing of Granular Materials). This method requires a front-end loader to dump a bucket of material, and backblade it. The sample is then obtained randomly from within the spread material. The delivery samples were tested in the Downsview laboratory, except on two contracts where all samples used for comparison were tested in the field laboratory. The intent was to have both sets of samples used for comparison tested in the same laboratory, either the field or the Downsview laboratory.

Testing was carried out according to method LS-602 of the MTC Laboratory Testing Manual.

3.2 Statistical Evaluation

As in Part I, in order to compare the two sets of results, stockpile and delivery, the statistical method known as hypothesis testing of means and variances was employed. This exercise determines whether the two sets of data represent the same population. Statistical analyses were carried out at a significance level of $\alpha = 0.05$ or a confidence level of 95%.

One objective of Part I attempted to determine whether handling, transporting, placing and spreading operations caused a breakdown in the particles. The report concluded that there was no significant breakdown of particles.

In Part II, the only source of difference in test results which was considered was that produced by segregation. Both differences in variances and means were examined. All Granular A in this study was controlled under Special Provision 331, Feb. 1982.

The figures are divided into two halves. One half shows, for each project, the normal distribution estimate for the population of the test results for each sieve for each point of sampling. The other half of the figure is the normal distribution of the split portion of the sample. The number of samples, the mean and the standard deviation are also shown. The Gradation Summaries figures, which appear at the end of the distribution curves for each project, show the mean gradation for each point of sampling.

The symbols used for statistical terms in this report are:

- $\bar{X}$ for mean
- σ for standard deviation and
- n for number of sample test results.

4.1 Stockpiling and Sampling

The source of Granular A was Regan Pit, Granular Inventory No. N2-163. The stockpile was built using a stacker and a front-end loader. The front-end loader removed material from the cone which the stacker created as the material dropped onto the stockpile. It then dumped the material into piles over the levelled area of the stockpile. The piles were subsequently levelled into a 1.5 m layer. The stockpile was built in five layers.

Acceptance samples were obtained from the stockpile at a random time by having the front-end loader mix the stacker-coned material. A sample was then taken from a bladed dump using the random area method. This contract was the first project in the study, and construction of the stockpile and acceptance sampling was well under way at the time this study was initiated. Therefore, only 3 acceptance sample splits were obtained by the time construction of the stockpile was completed.

A total of 36 stockpile samples were tested at the field laboratory located at Manchester, and a total of 32 delivery samples were taken and tested at the Downsview laboratory. The 3 stockpile sample splits were considered to contain insufficient data for analysis. Therefore, 12 delivery sample splits were tested in the same field laboratory that the stockpile samples were tested in.

Analyses of the delivery samples tested at Downsview with the delivery sample splits tested in the field laboratory compared very well. Therefore, even though the delivery set used for the study analysis had only 12 samples, it was felt that they adequately represented the material.

4.2 Analysis and Conclusions

In comparing the 12 delivery samples against the 36 stockpile samples, both sets of data being tested at the Manchester laboratory, the following conclusion can be made:

There was a significant difference in the mean gradation test results.

There was a significant difference in the variances of both sets of data.

These differences show up as the delivery samples being somewhat finer and considerably less variable than the stockpile samples. Figures 1 to 7 illustrate the results.

In comparing the 12 delivery samples, tested at the field laboratory, against the 32 delivery samples tested in the Downsview laboratory, it was found that:

There was no significant difference between the means, and

No significant difference between the variances.

Therefore, the field laboratory compared very well with the Downsview laboratory in both accuracy and precision.

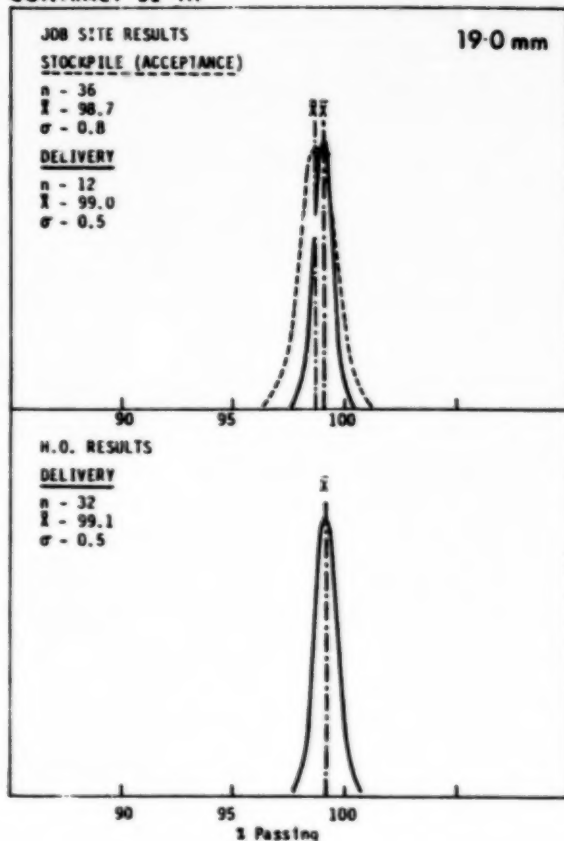


Figure 1

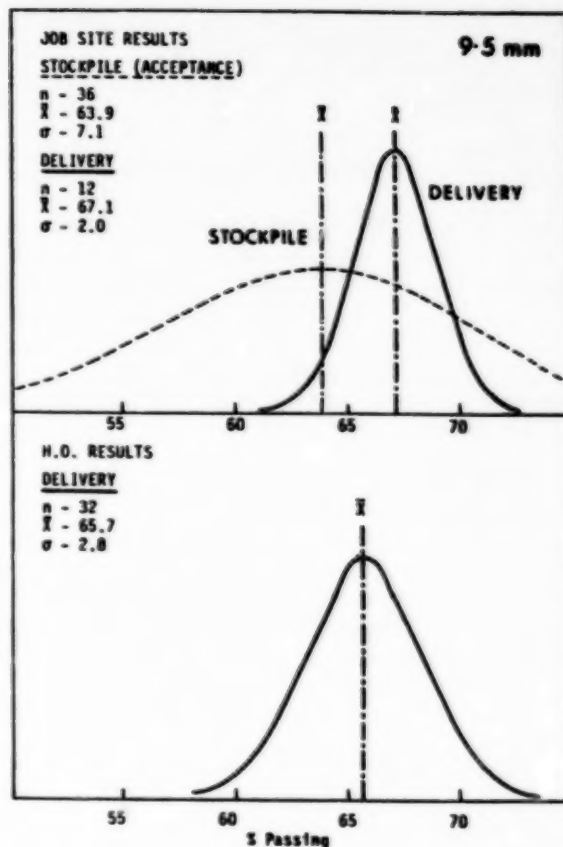


Figure 2

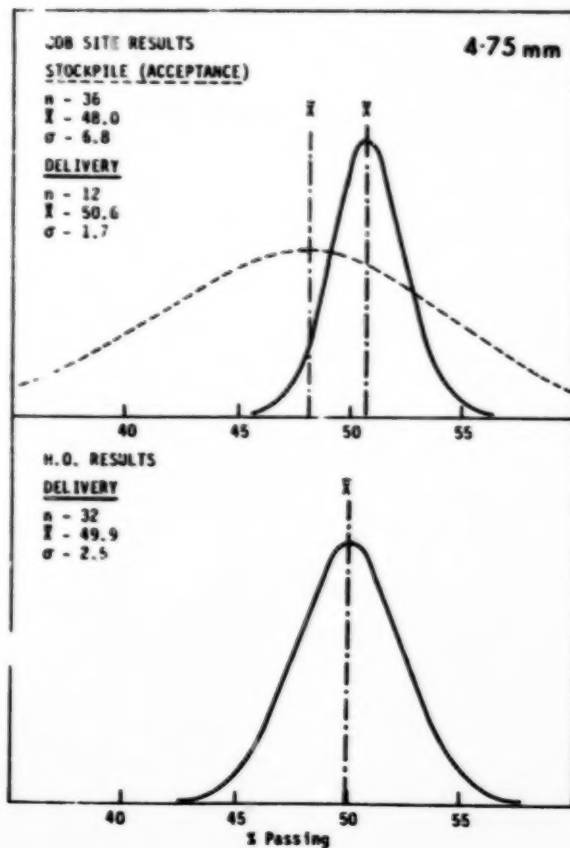


Figure 3

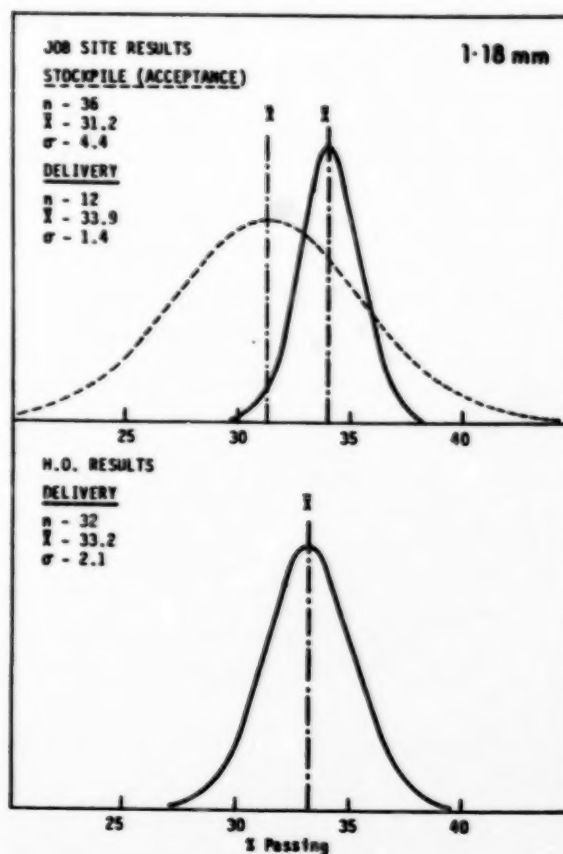


Figure 4

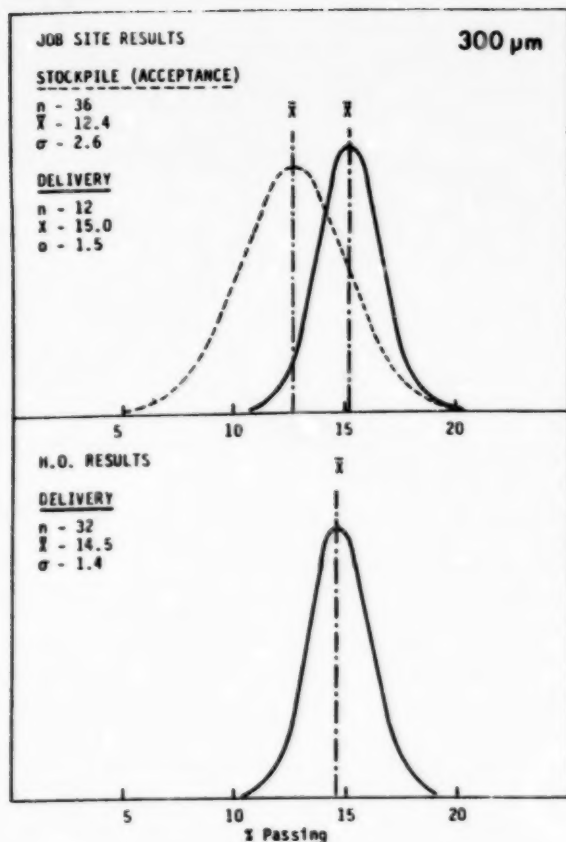


Figure 5

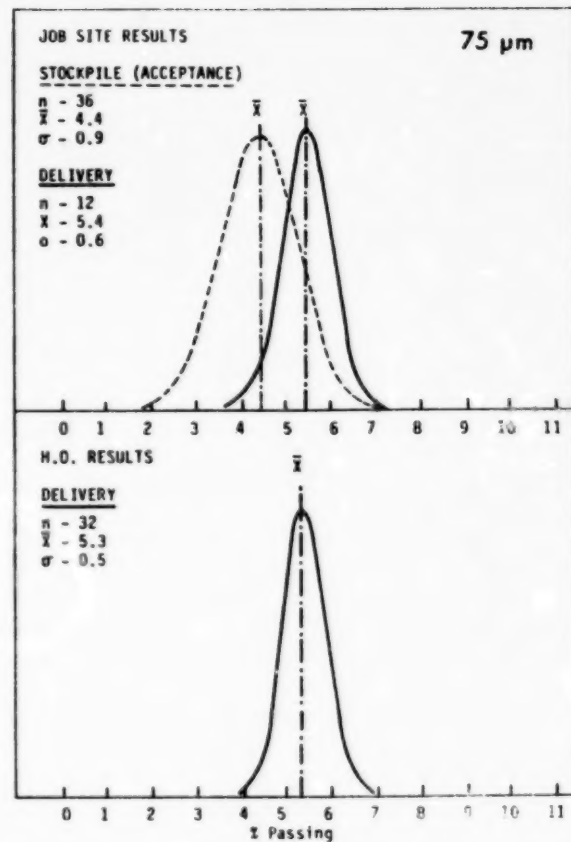


Figure 6

GRADATION SUMMARIES

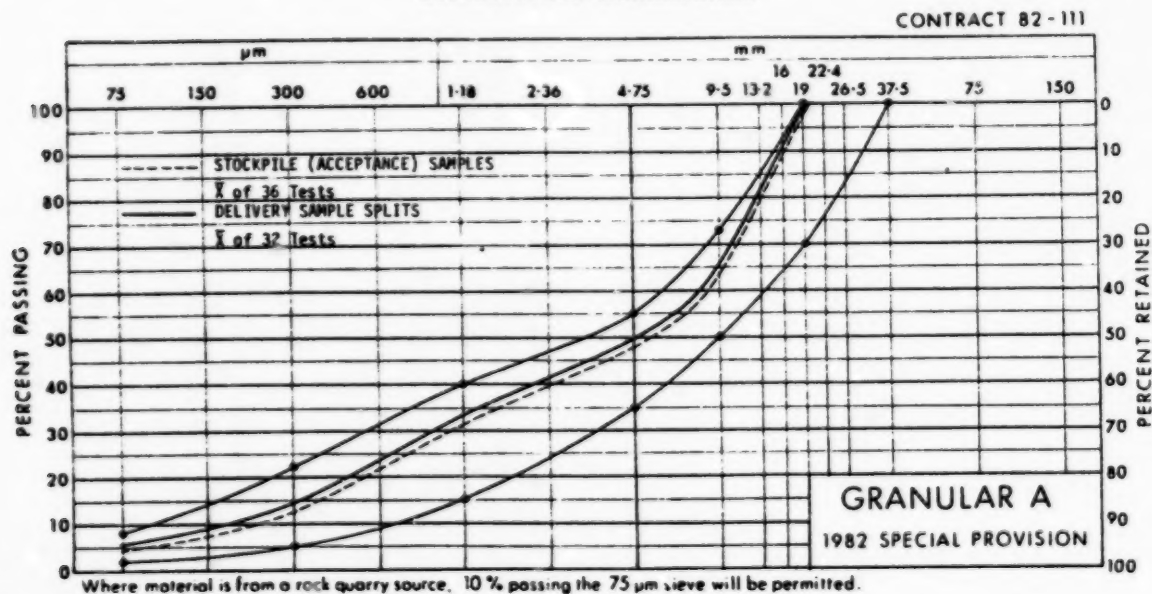


Figure 7

5. PROJECT 1A: CONTRACT 82-111
HWY. 7, CENTRAL REGION

5.1 Stockpiling and Sampling

This project was called 1A as it was the same contract and source as the last project, but with a different stockpile. On this project, it was decided to look at end of belt samples, as well.

After the stockpile was started, one of the front-end loaders broke down and, as a result, two large cones of some 8 000 t each were produced by the stacker. These cones were later levelled off into two layers, for a total height of some 3 to 4 m.

The depletion of the stockpile by the delivery trucks was faster than the production capabilities, with the result that some truck loads included material just coned onto the stockpile. This material was hauled to the road at the same time as material from the stockpile. The front-end loader operator continued to build the stockpile as he had time.

The stockpile acceptance samples were obtained, at a random time, from the freshly coned material. The front-end loader thoroughly mixed, picked up, dumped, and then spread the material. The sample was taken at a randomly selected location from the bladed area. The end of belt samples were obtained at the same time as the stockpile acceptance samples. A bucket was passed five or six times through the stream of material.

The following sets of samples were taken:

- a) 36 stockpile acceptance samples tested at the field laboratory at Manchester.
- b) 31 stockpile acceptance sample splits tested at the Downsview laboratory.
- c) 32 delivery samples tested at the Downsview laboratory.
- d) 32 end of belt samples also tested at the Downsview laboratory.

5.2 Analysis and Conclusions

In comparing the 31 stockpile samples and the 32 delivery samples both tested at the Downsview laboratory, the following conclusions were drawn:

There was a significant difference between the means on all sieves except the 19.0 mm and 75 μ m.

There was no significant difference in variances between the two sets of data.

The delivery samples again showed a finer gradation than the stockpile samples. However, the variance of the stockpile and delivery samples was the same. Figures 8 to 14 detail these results.

In comparing the 36 stockpile samples tested in the field laboratory against the 31 stockpile samples tested at the Downsview laboratory, the analysis indicated that there was no significant difference in the means or variances between the two sets of data, and that the laboratories had the same degree of accuracy and precision.

A comparison was made between the 31 stockpile samples and the 32 end of belt samples which were all tested at the Downsview laboratory. It was found that:

There was no significant difference between the means.

There was no significant difference in the variances.

The stockpile and end of belt results give essentially the same results, except that the end of belt samples were slightly coarser in gradation. This was found to be true as well in a comparison of end of belt and stockpile samples taken on two projects in previous studies. The results are shown on Figure 15.

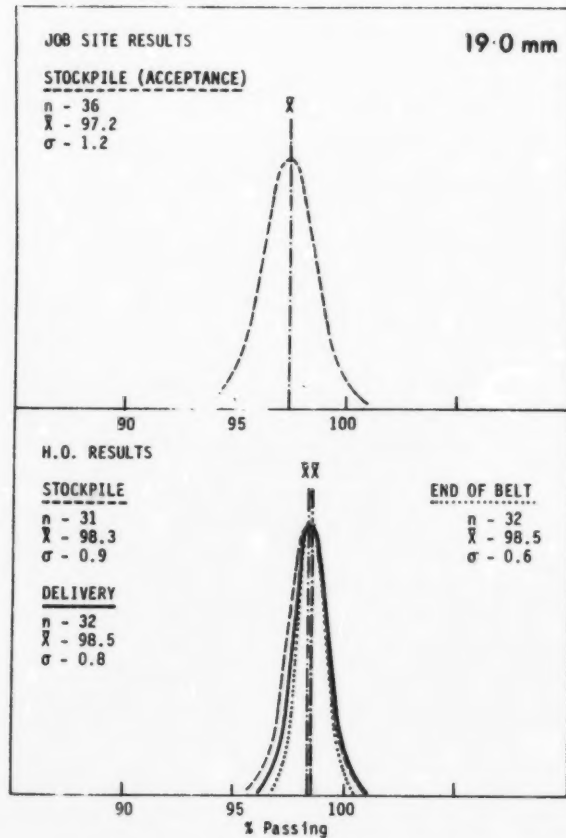


Figure 8

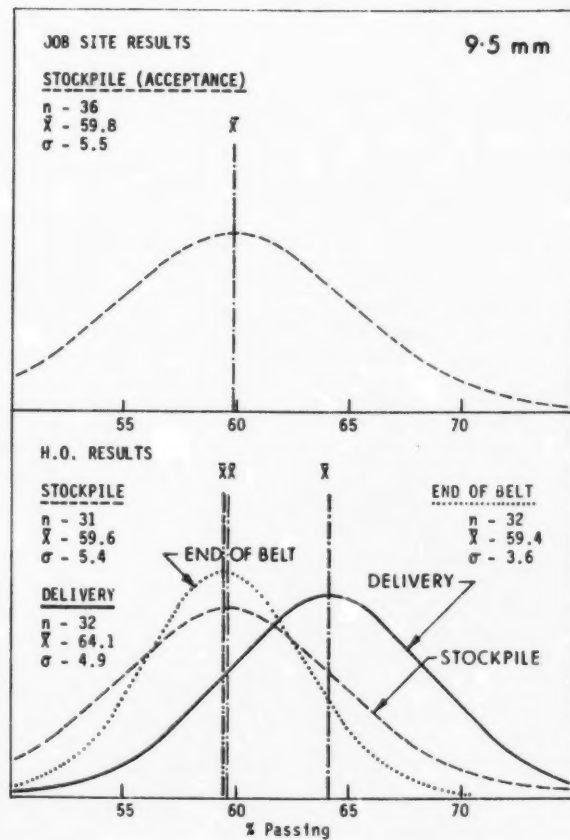


Figure 9

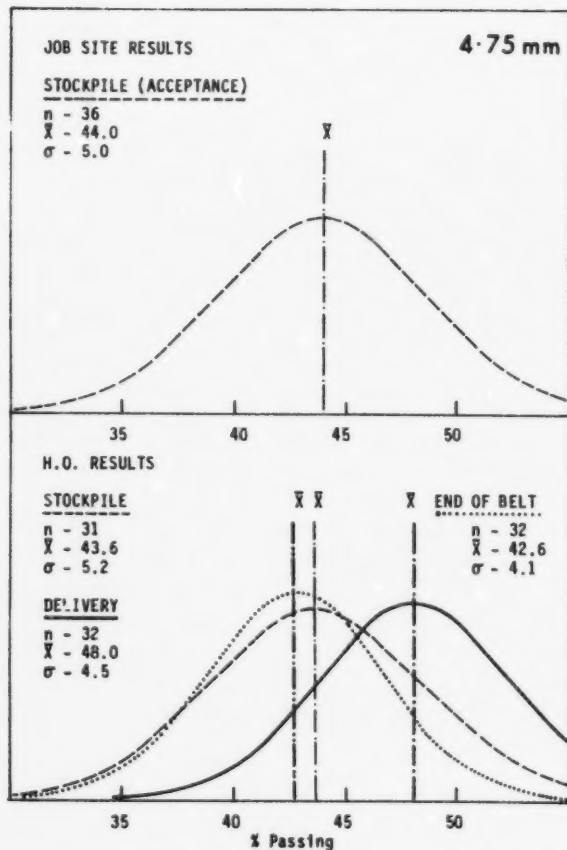


Figure 10

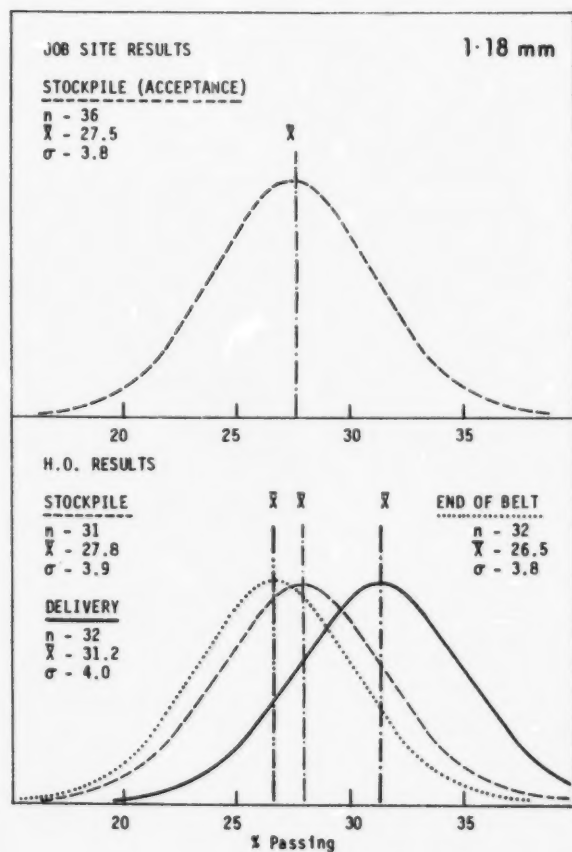


Figure 11

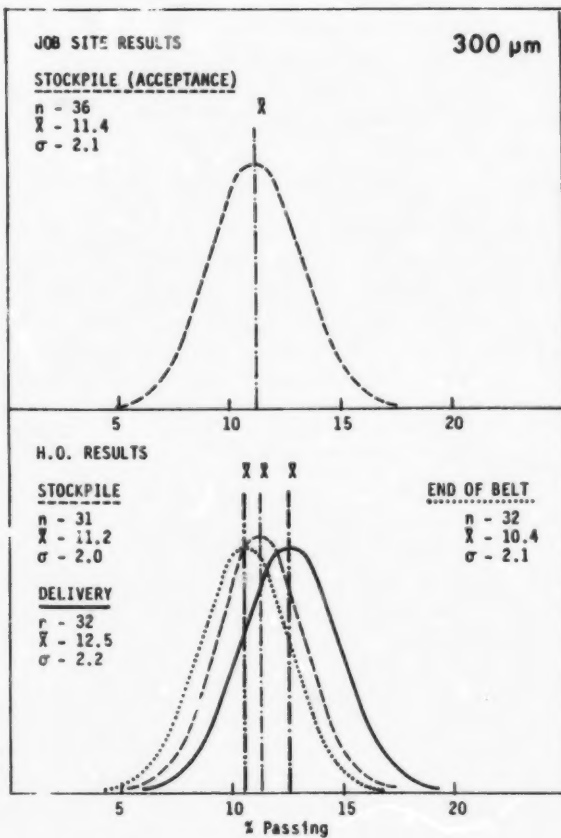


Figure 12

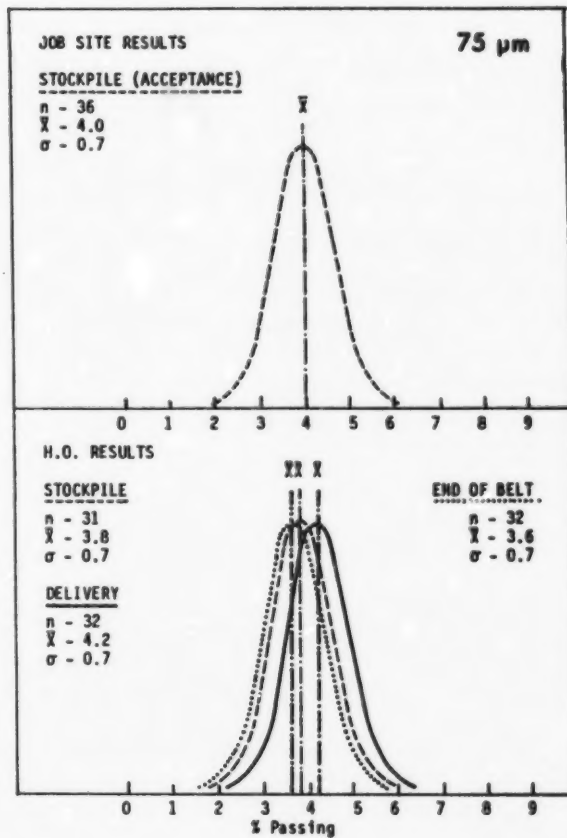


Figure 13

GRADATION SUMMARIES

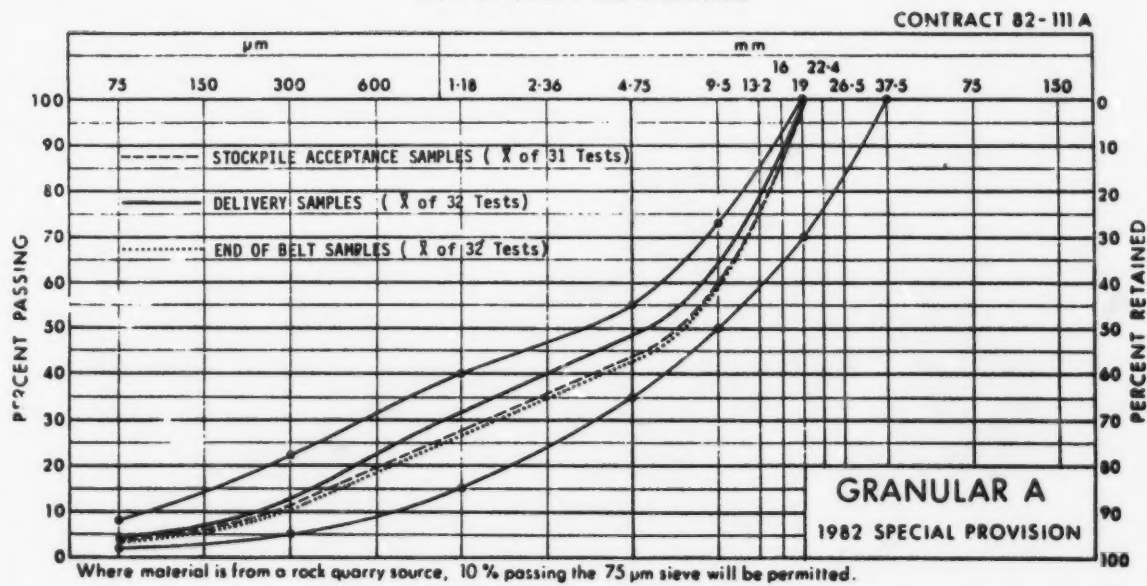


Figure 14

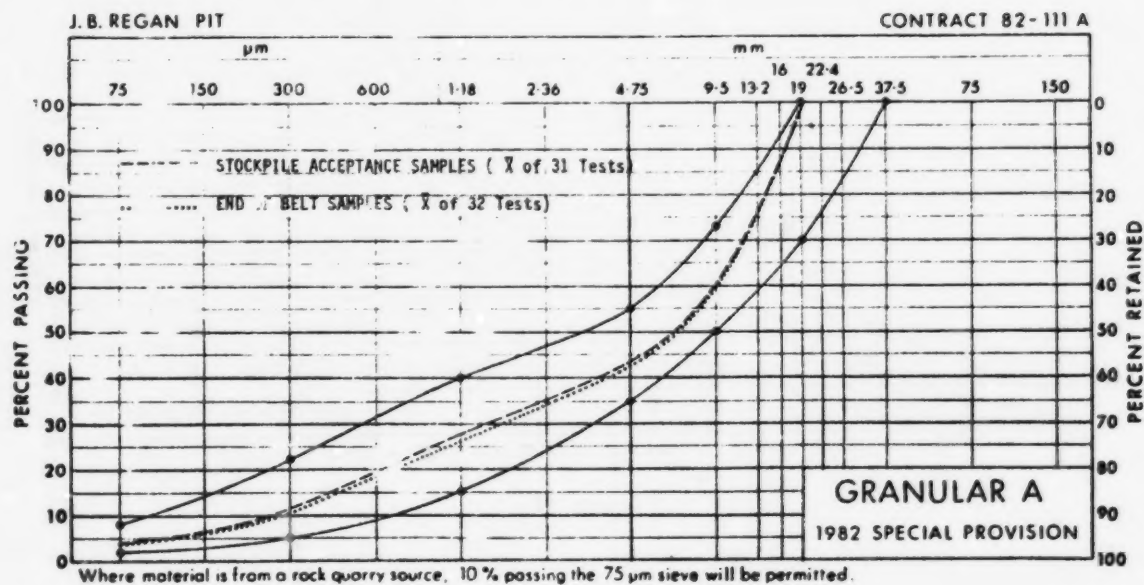
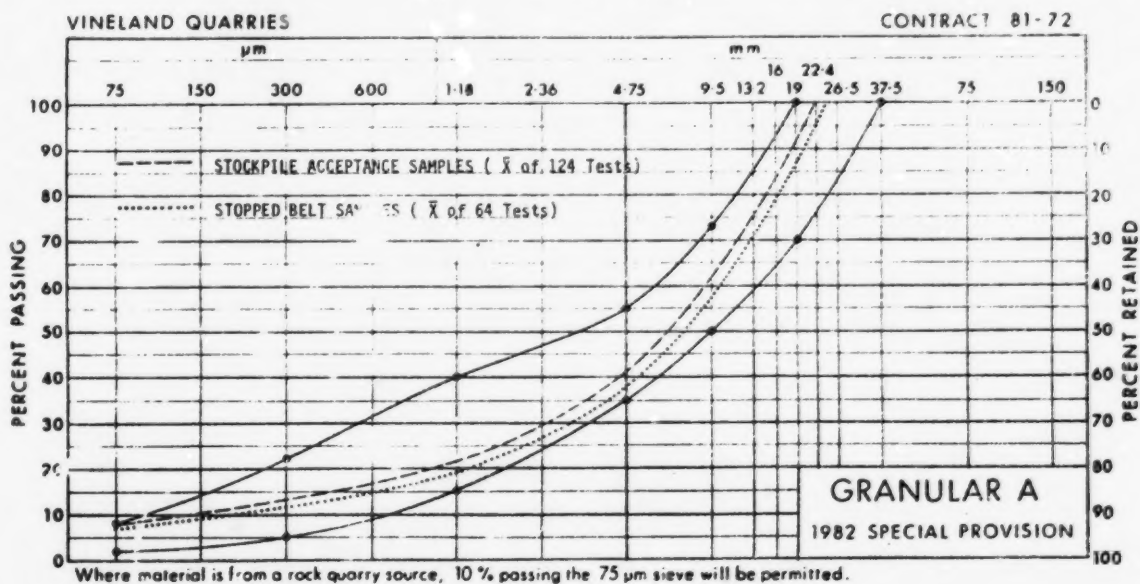
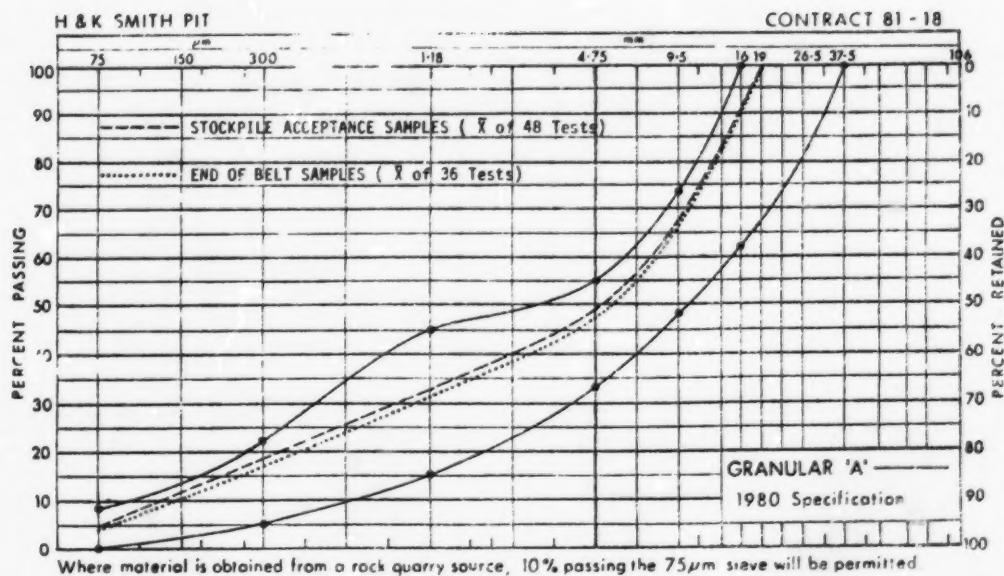


Figure 15

6. PROJECT 2: CONTRACT 82-83
HWY. 20, CENTRAL REGION

6.1 Stockpiling and Sampling

The source of the Granular A was Lincoln Quarries, Granular Inventory No. N3-35. The stockpile was built by trucks dumping onto the stockpile. The piles were then levelled by a front-end loader. The crusher's conveyor belt loaded the material into a holding bin which had relatively flat sides.

Because of the concern of segregation, the sampling for acceptance was taken from material dumped on the quarry floor and mixed by the front-end loader. The truck from which the sample was taken was randomly chosen.

This contract was underway when designated for the study. The comparison was, therefore, between stockpile acceptance samples and delivery samples tested in the field laboratory located in the quarry. The numbers of samples taken were 200 stockpile acceptance samples tested in the field laboratory, 32 delivery samples also tested at the quarry field laboratory, and 31 delivery splits tested at the Downsview laboratory.

Some of the stockpile acceptance test results were out of specification and resulted in price adjustment to a few lots of Granular A. The testing done under the study confirmed these results.

6.2 Analysis and Conclusions

In comparing the 200 stockpile samples used for acceptance against the 32 delivery samples tested in the same laboratory, the following conclusions were reached:

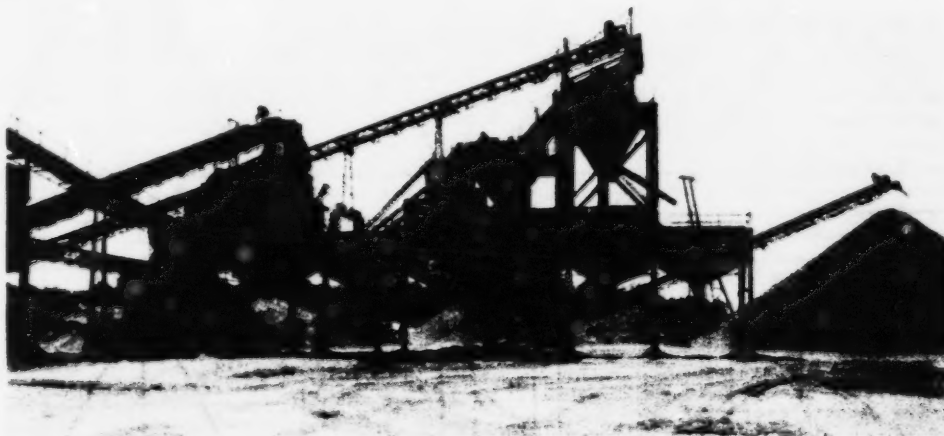
There was no significant difference between the means of the two sets of data.

There was no significant difference between the variances of the two sets of data.

From a statistical point of view, both sets of data represented the same population or material. Figures 16 to 22 detail the analysis of these test results.

In comparing the 32 delivery samples tested at the field laboratory with the 31 delivery samples tested at the Downsview laboratory, the results showed that there was no significant difference in the means between the two sets of results, except on the 300 and 75 μ m sieves, and that there was no significant difference in the variances.

Both laboratories had the same accuracy and precision.



Truck Loading Bins - Lincoln Quarries

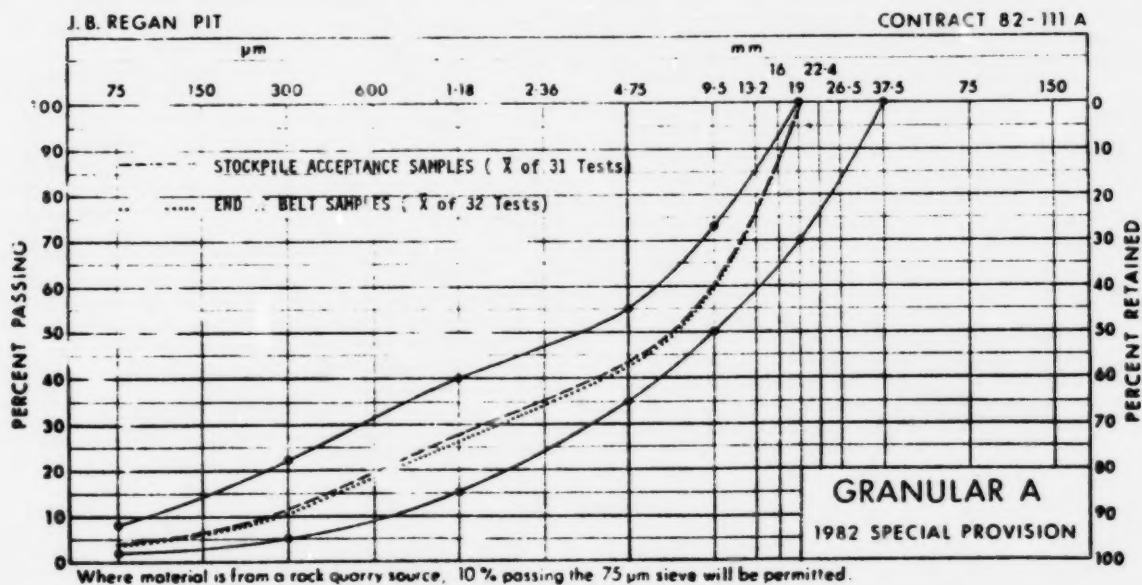
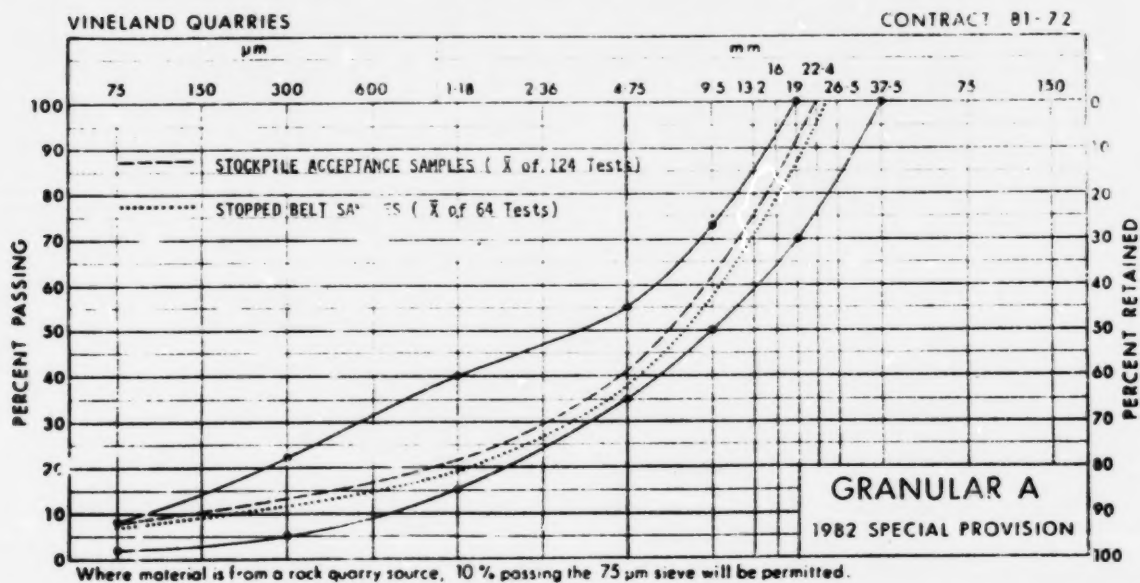
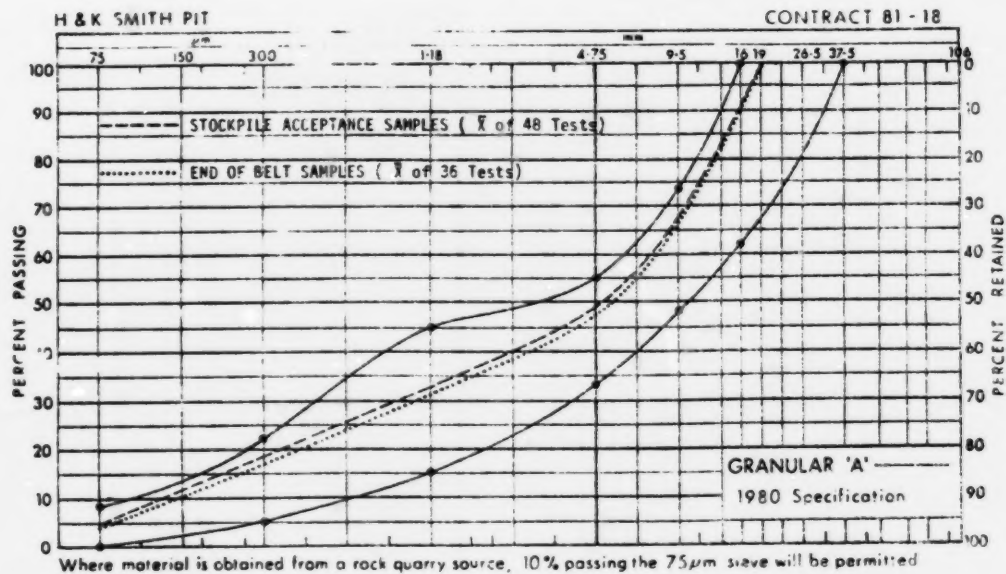


Figure 15

6. PROJECT 2: CONTRACT 82-83
HWY. 20, CENTRAL REGION

6.1 Stockpiling and Sampling

The source of the Granular A was Lincoln Quarries, Granular Inventory No. N3-35. The stockpile was built by trucks dumping onto the stockpile. The piles were then levelled by a front-end loader. The crusher's conveyor belt loaded the material into a holding bin which had relatively flat sides.

Because of the concern of segregation, the sampling for acceptance was taken from material dumped on the quarry floor and mixed by the front-end loader. The truck from which the sample was taken was randomly chosen.

This contract was underway when designated for the study. The comparison was, therefore, between stockpile acceptance samples and delivery samples tested in the field laboratory located in the quarry. The numbers of samples taken were 200 stockpile acceptance samples tested in the field laboratory, 32 delivery samples also tested at the quarry field laboratory, and 31 delivery splits tested at the Downsview laboratory.

Some of the stockpile acceptance test results were out of specification and resulted in price adjustment to a few lots of Granular A. The testing done under the study confirmed these results.

6.2 Analysis and Conclusions

In comparing the 200 stockpile samples used for acceptance against the 32 delivery samples tested in the same laboratory, the following conclusions were reached:

There was no significant difference between the means of the two sets of data.

There was no significant difference between the variances of the two sets of data.

From a statistical point of view, both sets of data represented the same population or material. Figures 16 to 22 detail the analysis of these test results.

In comparing the 32 delivery samples tested at the field laboratory with the 31 delivery samples tested at the Downsview laboratory, the results showed that there was no significant difference in the means between the two sets of results, except on the 300 and 75 um sieves, and that there was no significant difference in the variances.

Both laboratories had the same accuracy and precision.



Truck Loading Bins - Lincoln Quarries

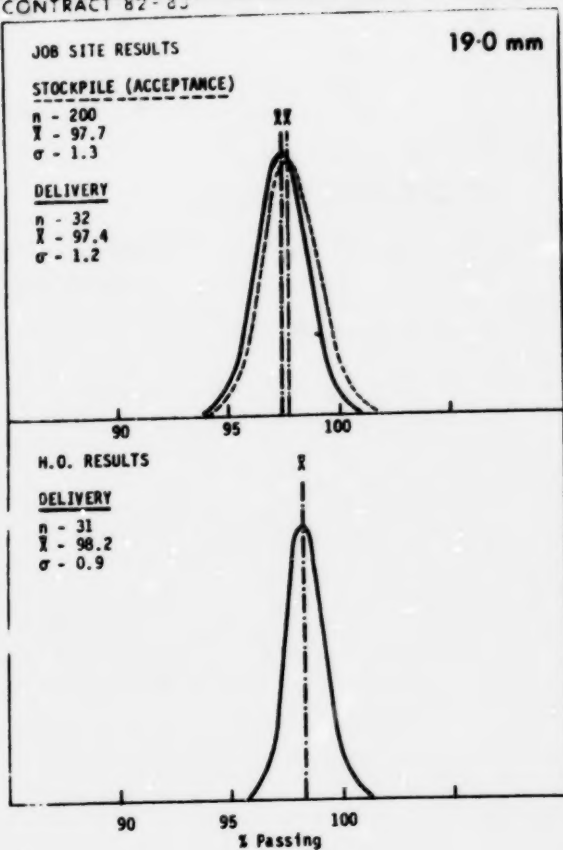


Figure 16

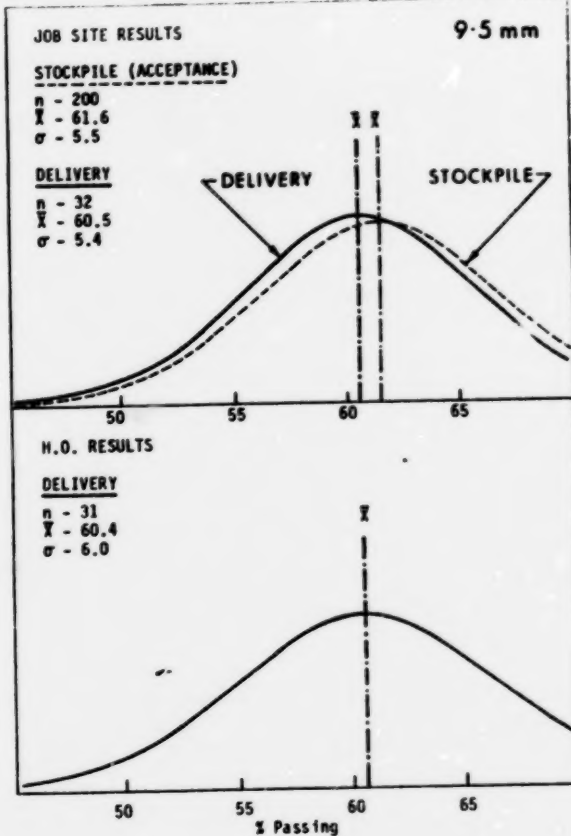


Figure 17

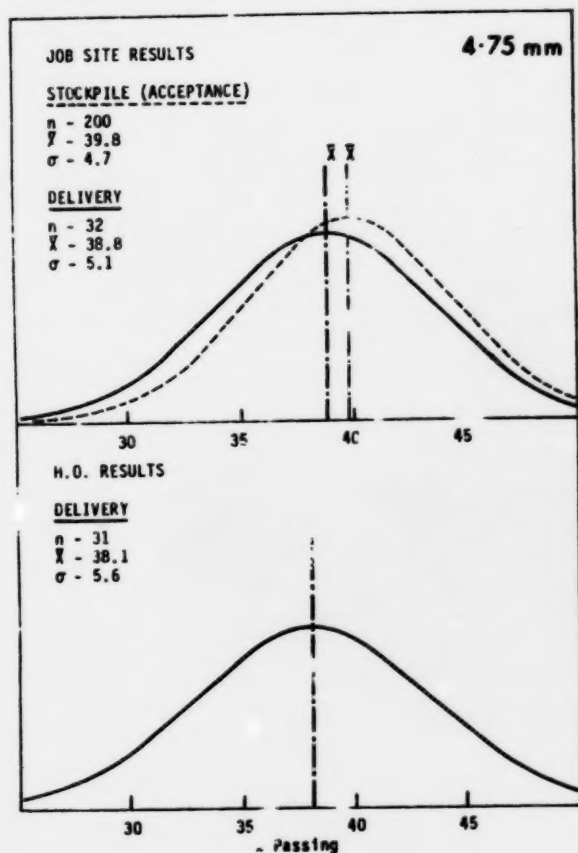


Figure 18

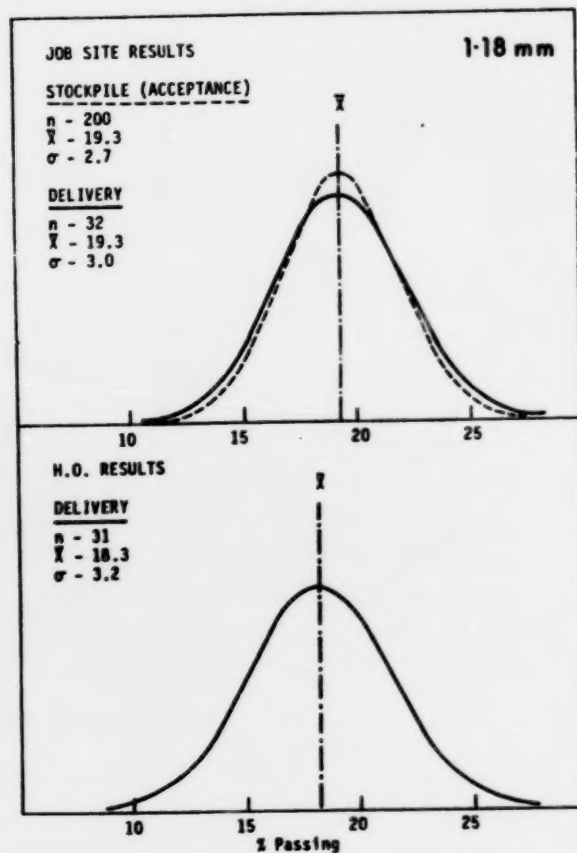


Figure 19

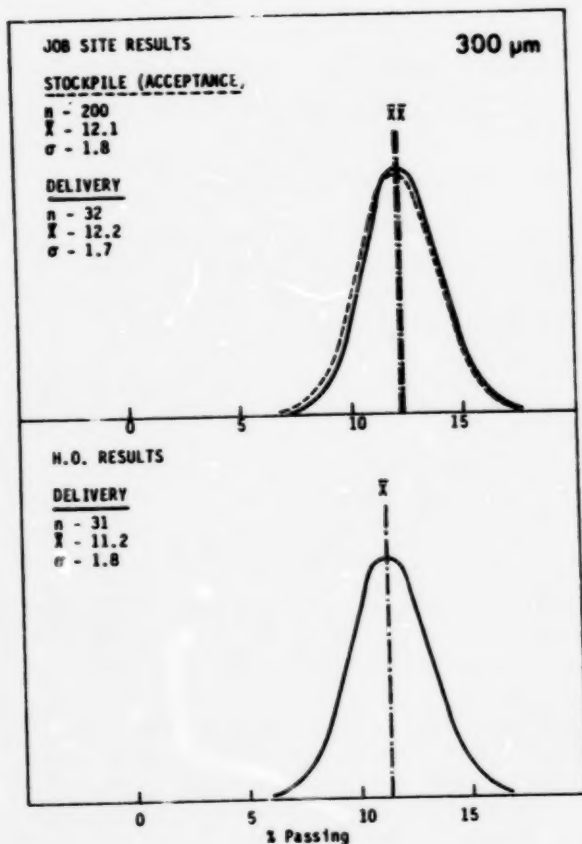


Figure 20

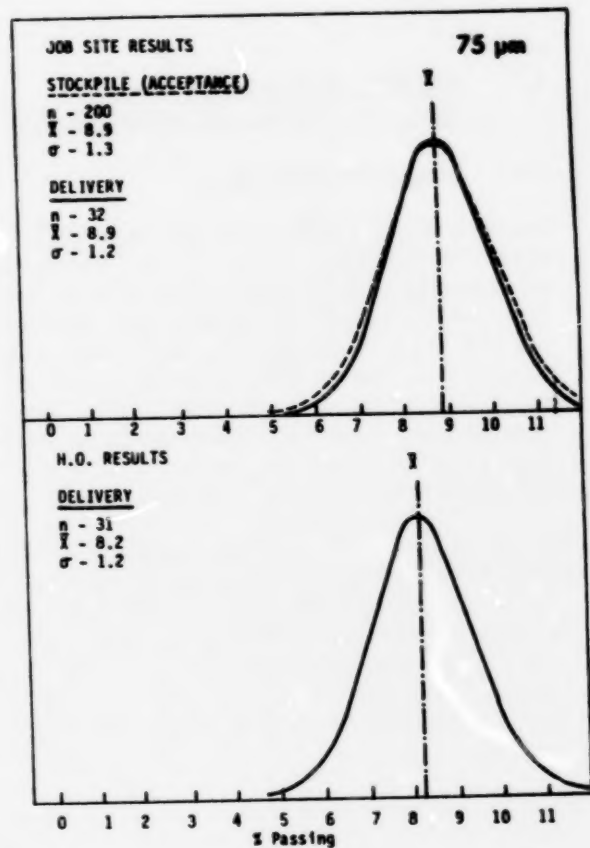


Figure 21

GRADATION SUMMARIES

CONTRACT 82-83

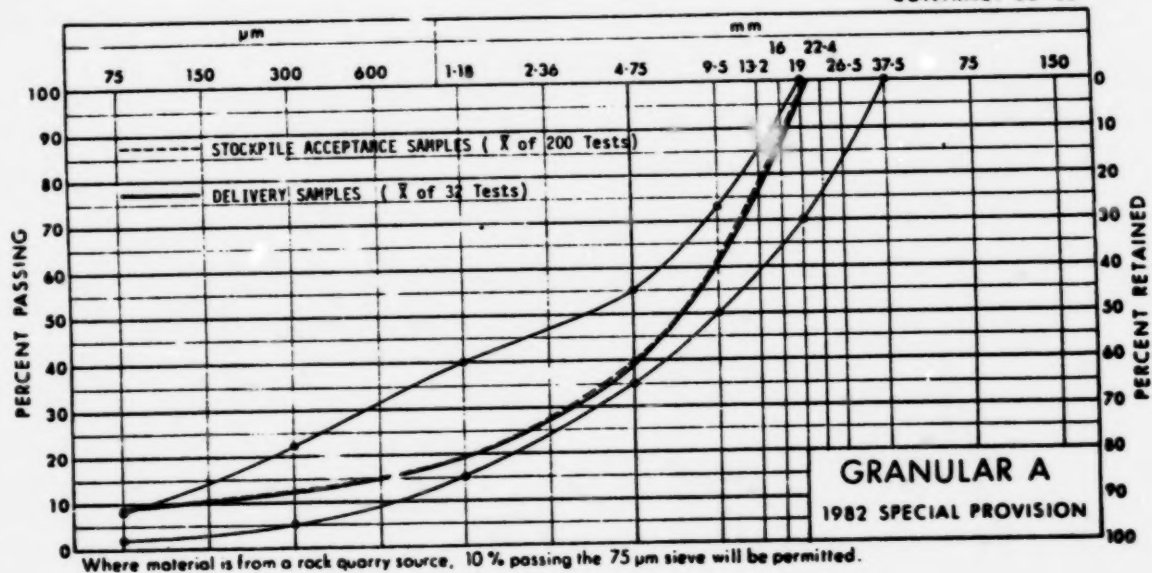


Figure 22

7. PROJECT 3: CONTRACT 83-201
HWYS. 17 AND 94, NORTHERN REGION

7.1 Stockpiling and Sampling

The Granular A was produced from the F. Scott Pit, Granular Inventory No. N5-96. A stacker was used in the construction of the stockpile by coning onto the levelled area of the stockpile. The coned material was then pushed over the levelled area, in layers of about 0.3 m, by a front-end loader. At a random time, the field technician sampled the entire layer by randomly taking sufficient shovelfuls to fill a sample bag.

Some 23 stockpile samples were taken by MTC field staff for acceptance. However, due to a misunderstanding, only 10 stockpile sample splits were obtained for testing in the Downsview laboratory. A total of 31 delivery samples were obtained by a Soils and Aggregates technician for Head Office testing.

Due to the small number of stockpile sample splits and the lack of agreement with the field stockpile test results, the conclusions for this project were viewed with some reservations.

7.2 Analysis and Conclusions

In comparing the 10 stockpile samples against the 31 delivery samples, both tested at the Downsview laboratory, the following statements can be made:

There was no significant difference between the means.

There was a significant difference in the variances on the 9.5, 4.75, and the 1.18 mm sieves and no significant difference on the remaining sieves.

In comparing the 23 stockpile samples tested by the field laboratory with the 10 stockpile samples tested at the Downsview laboratory, it was found that there was no significant difference between the means and no significant difference in the variances of the coarse aggregate (i.e. 19.0, 9.5 and 4.75 mm sieves), however, there was a significant difference in variances of the fine aggregate. The results of the analysis are shown on Figures 23 to 29 inclusive.

The test for significant difference between two sets of parameters is a relative test as it is a function of the number of samples, the mean and the standard deviation. It is very dependent on the number of samples used to estimate the population parameters. For example, a difference in means of 2.0 may be significant if $n_1 = 100$ and $n_2 = 30$, however, it most probably would not be significant if $n_1 = 10$ and $n_2 = 30$. This is because $n_1 = 100$ is a better estimate of the population mean than $n_1 = 10$, and therefore, should be more accurate.

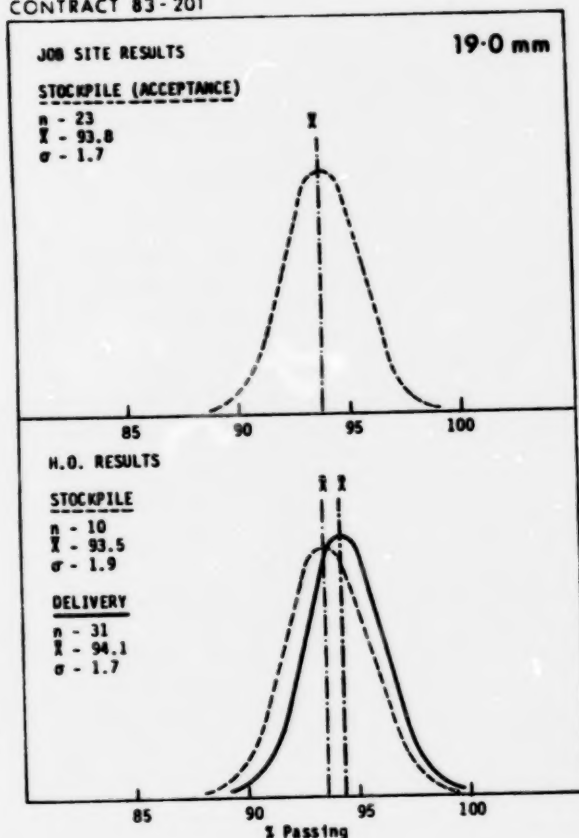


Figure 23

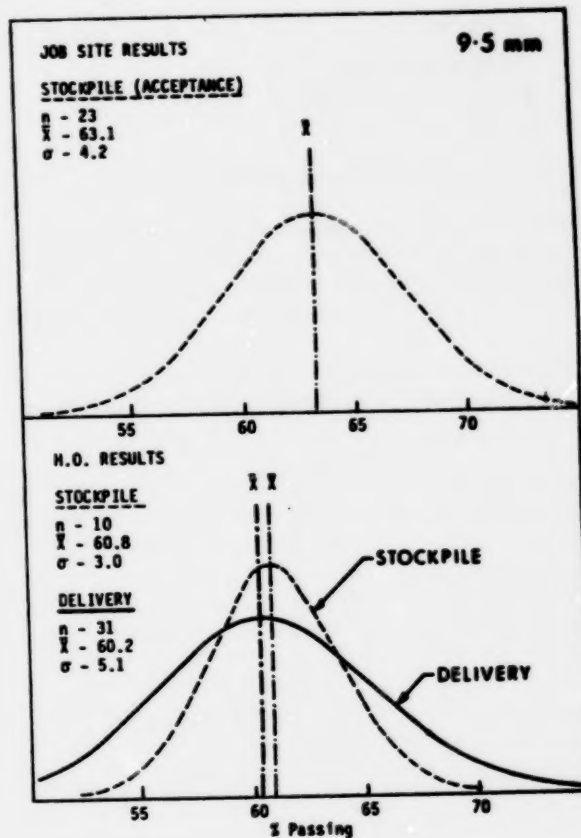


Figure 24

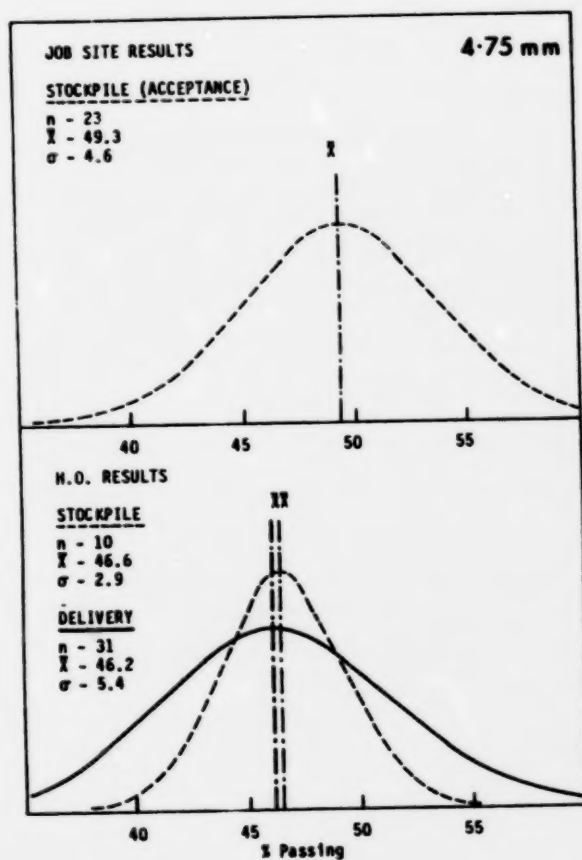


Figure 25

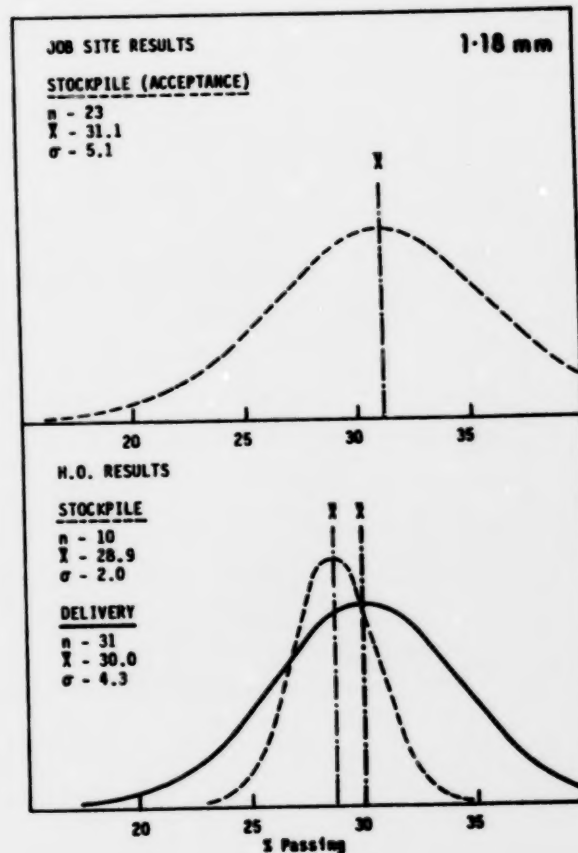


Figure 26

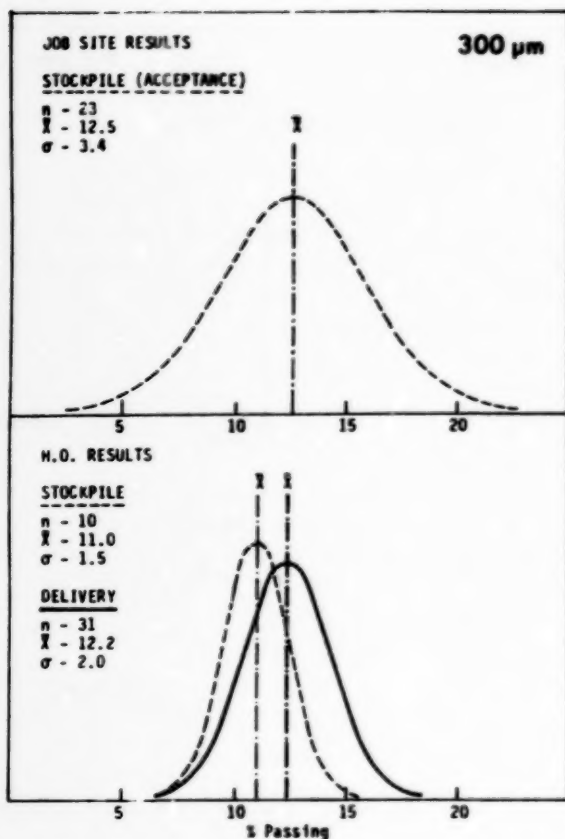


Figure 27

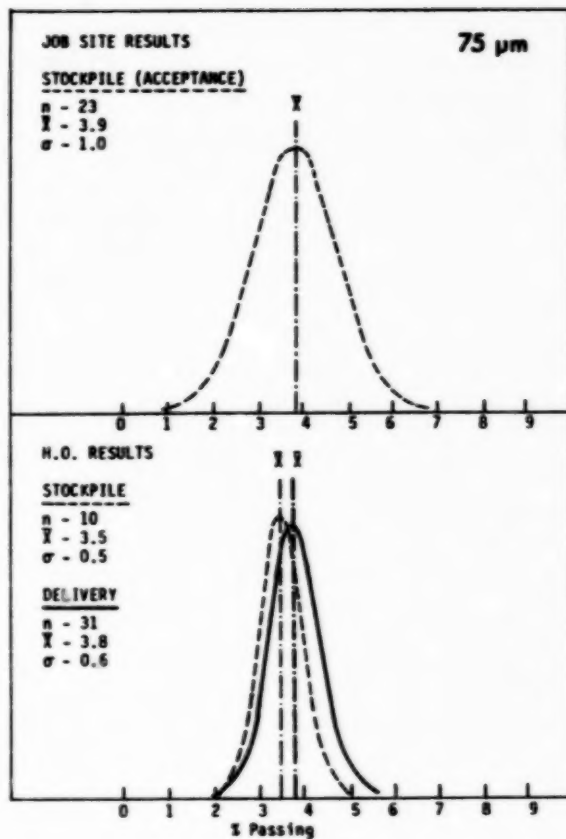


Figure 28

GRADATION SUMMARIES

CONTRACT 83-201

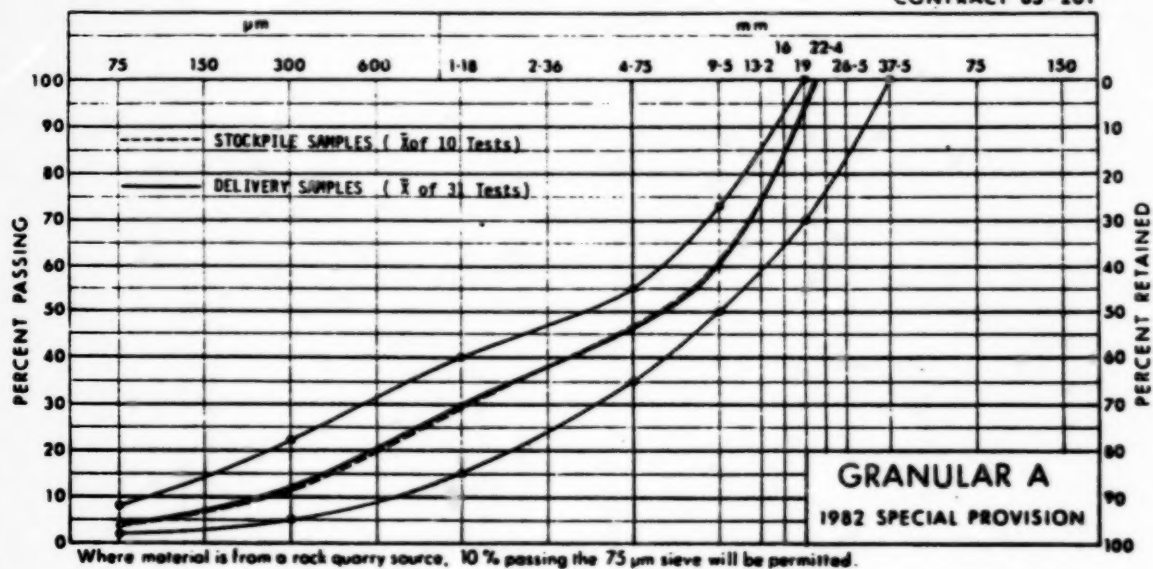


Figure 29

8. PROJECT 4: CONTRACT 83-21
Rwy. 2, CENTRAL REGION

8.1 Stockpiling and Sampling

The Granular A for this contract was produced from Lafferty Pit, Granular Inventory No. T7-15. The stockpile started off being built with a stacker, dropping material on to the stockpile, and with a track mount dozer used for levelling. As this apparently caused too much segregation, the procedure was changed. The stacker coned a 3 m high pile on the pit floor, and the front-end loader took bucket loads to the top of the stockpile, and levelled them.

The acceptance samples were originally taken from the top of the stockpile by filling a sample bag from one random location. When the stockpile construction method was changed, the sampling location moved to the coned material on the pit floor. The front-end loader obtained a bucket load from the cone, dropped and spread it, and the sample was obtained from one spot to the full depth of the spread. Following a field visit by one of the authors, the acceptance sampling location was moved back to the top of the stockpile as it was felt, at that time, that more representative samples could be obtained from that location.

Forty-eight stockpile acceptance samples were taken by the field technician, and tested at the laboratory located in the pit. Nineteen stockpile sample splits were obtained for Head Office testing. Thirty delivery samples were taken to be tested at the Downsview laboratory.

8.2 Analysis and Conclusions

In comparing the 19 stockpile sample splits with the 30 delivery samples, all tested at the Downsview laboratory, the following conclusions can be drawn:

There was no significant difference between the means of both sets of data.

There was no significant difference in the variances, except on the 75 um sieve.

The above statements indicate that there was no significant segregation taking place from the stockpile sampling to the delivery sampling. However, a review of the gradation chart, Figure 36, shows a slightly finer gradation for the delivery samples, even though both sets of data statistically represent the same population.

A comparison was made between the 19 stockpile samples tested for acceptance in the field laboratory, and the 19 sample splits that were received at the Downsview laboratory. The analysis indicates that there was no significant difference in means or variances indicating the same degree of precision and accuracy.

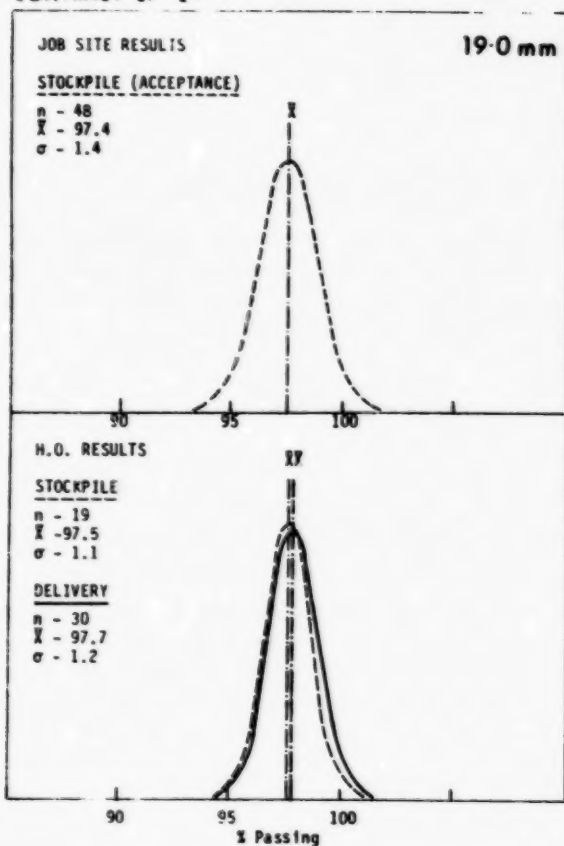


Figure 30

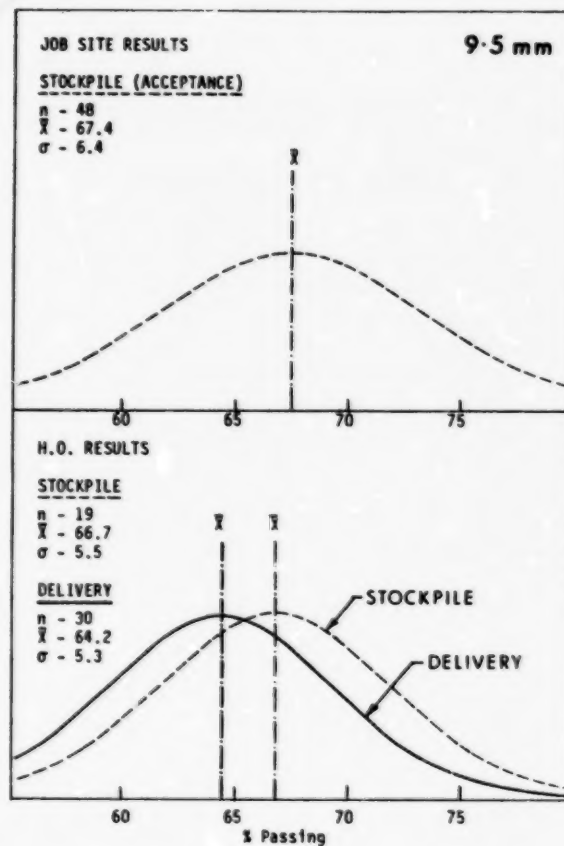


Figure 31

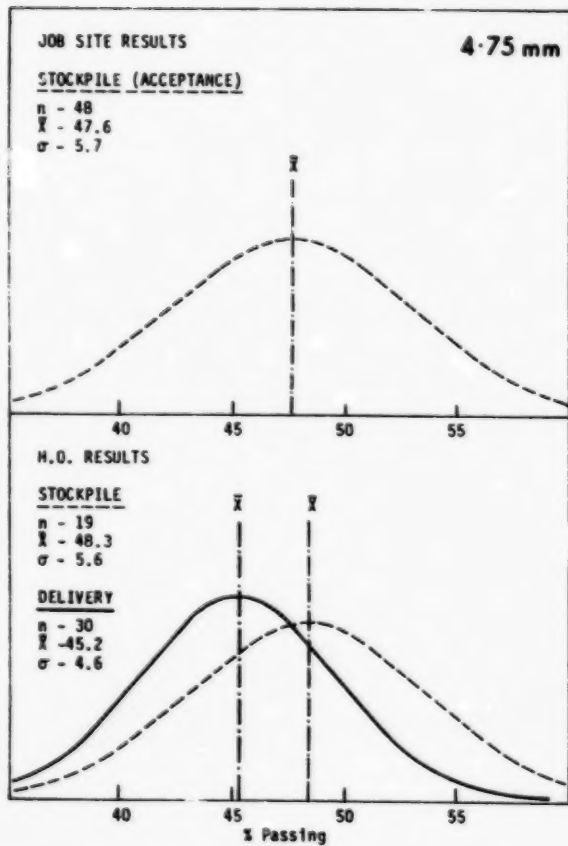


Figure 32

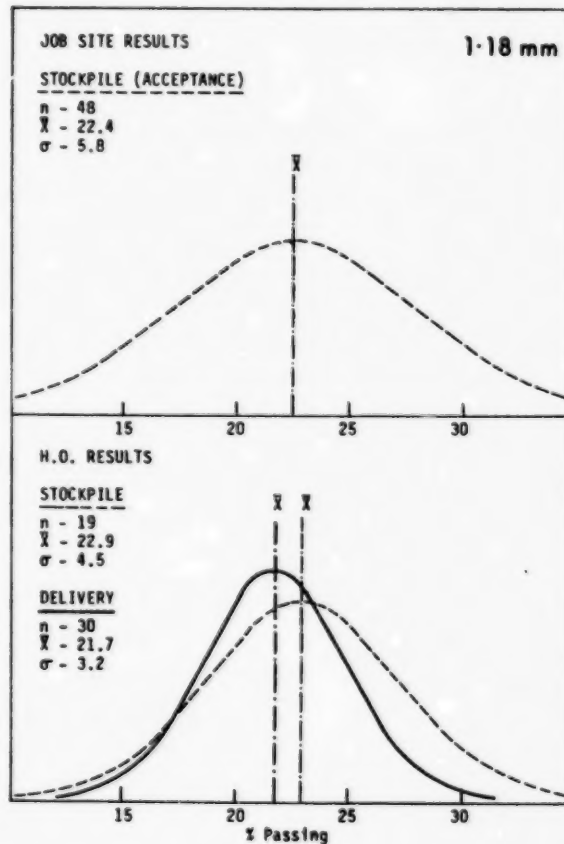


Figure 33

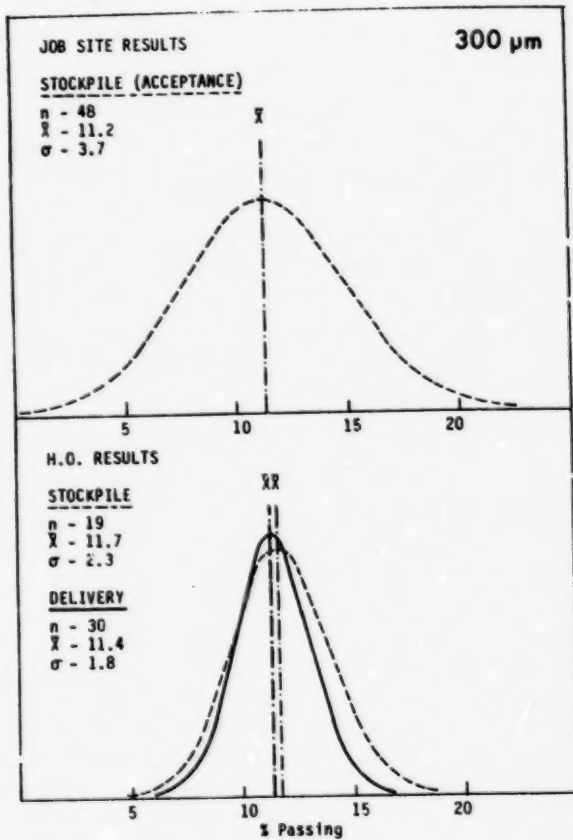


Figure 34

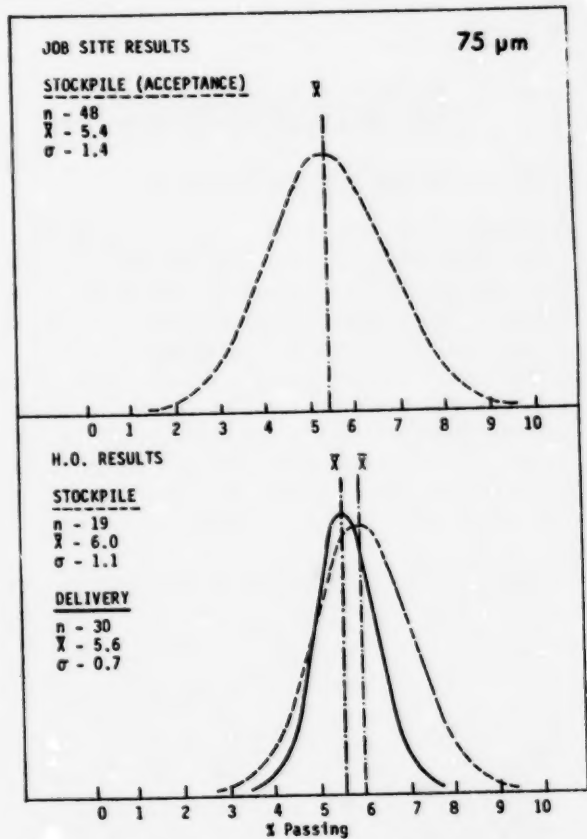


Figure 35

GRADATION SUMMARIES

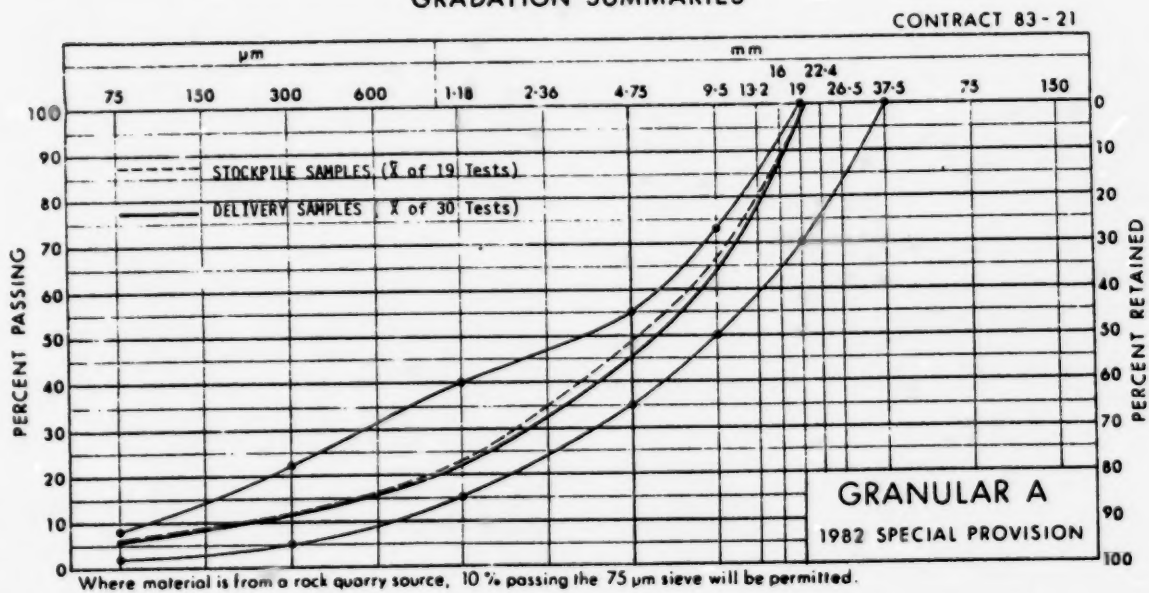


Figure 36

9. PROJECT 5: CONTRACT 83-19
HWY. 401, EASTERN REGION

9.1 Stockpiling and Sampling

Hannah Quarry was the source of Granular A for this contract. The Granular Inventory No. is N3-35. The stockpile was built in the quarry and, due to lack of space, ended up with two high peaks almost as if coned. A front-end loader picked up material from where the crusher dropped it on the quarry floor and carried it to the stockpile, and then levelled the piles. Trucks were loaded both from the stockpile and from where the crusher dropped the material.



Crushing operation prior to stockpiling

The stockpile acceptance samples were obtained at random times. The field technician took material from up to six different locations to fill a sample bag.

Sixty samples, tested in the field laboratory, were taken for stockpile acceptance. Thirty-one of these were split for H.O. testing. Thirty delivery samples were taken and tested at the Downsview laboratory.

9.2 Analysis and Conclusions

Thirty-one stockpile sample splits were compared against 30 delivery samples, indicating that:

There was no significant difference in the means of the two sets of data.

There was a significant difference in the variances.

Significant amounts of segregation occurred during the stockpiling operation. This was indicated by the fact that delivery samples had a much greater variation than the stockpile samples. This greater variation of delivery samples was not what was expected or found in previous projects. In a review of the stockpiling operation, and the stockpile and delivery sampling methods and locations, an explanation for the cause of the significant variation in the delivery test data may be as a result of one or both of the following:

a) The stockpile was constructed in layers by a front-end loader in a very confined area. At the same time a couple of high cones were formed. These peaks were not levelled due to lack of space.

b) The stockpile sampling was carried out using random times for sampling. The sample was taken using up to six shovelfuls from several locations to fill the bag. Some unconscious bias could take place as each shovelful of material sampled was selected by the field technician.

A comparison was made between the 31 stockpile splits tested at the Downsview laboratory and the corresponding 31 stockpile samples tested at the field laboratory. The result indicates that there was the same degree of accuracy and precision between the two laboratories.

Figure 37 to 43 inclusive detail the results of the above analysis.

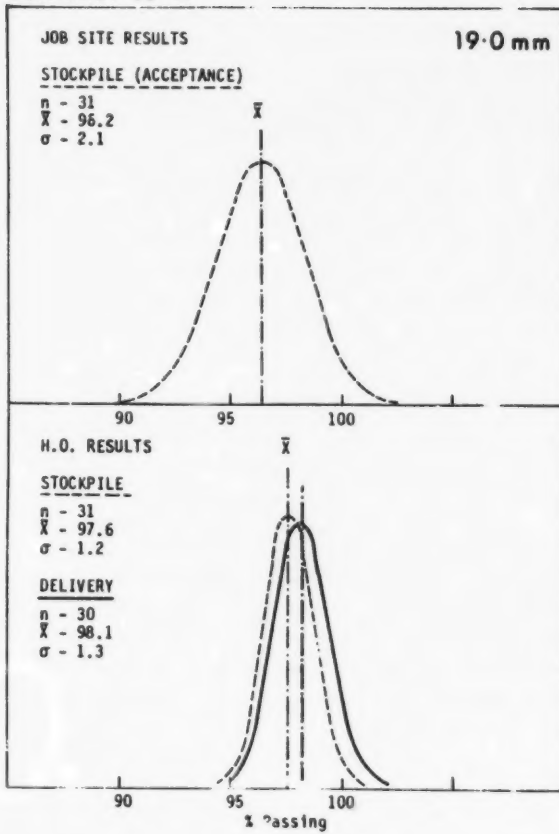


Figure 37

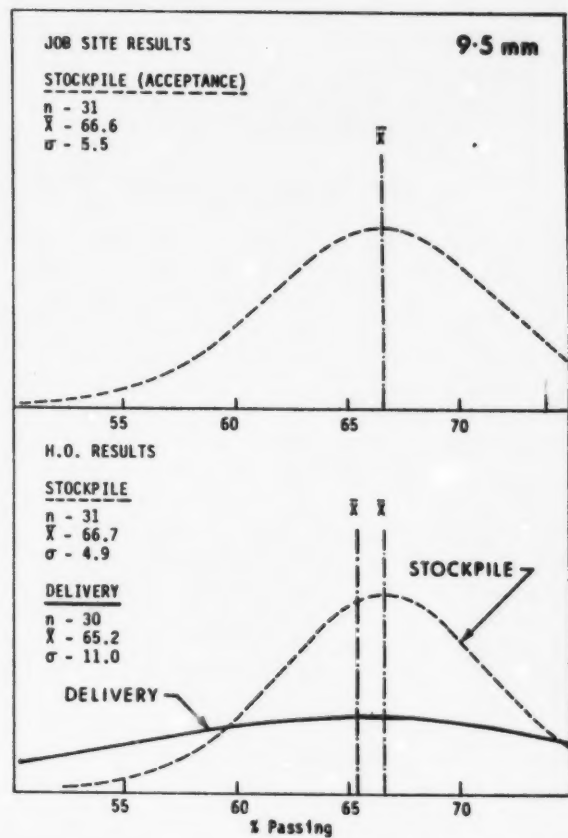


Figure 38

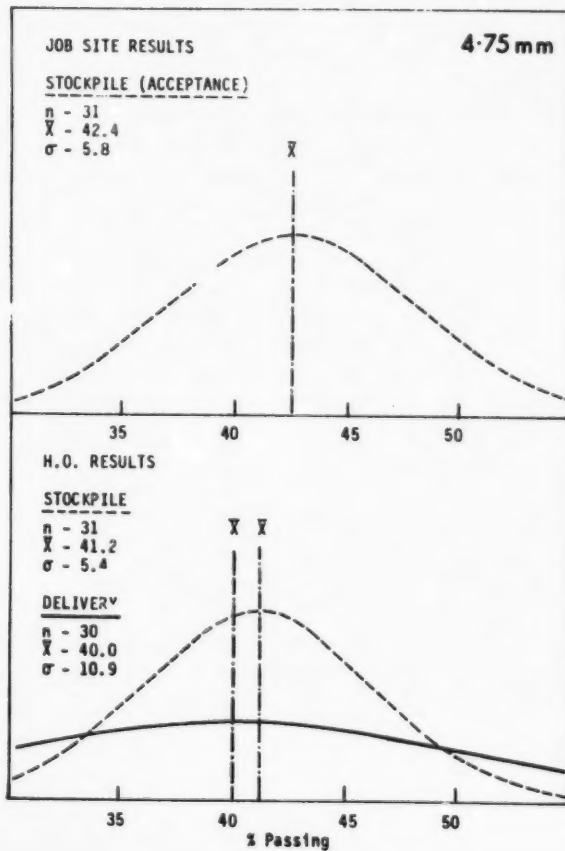


Figure 39

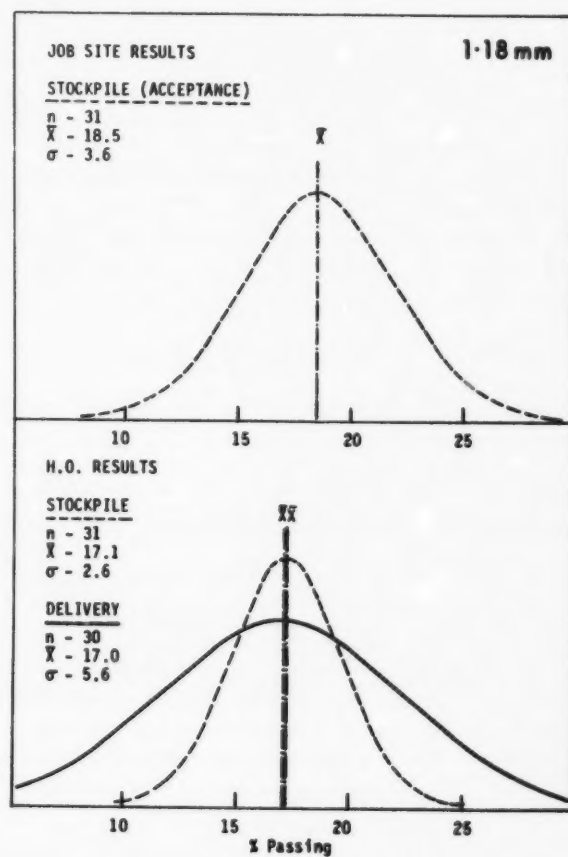


Figure 40

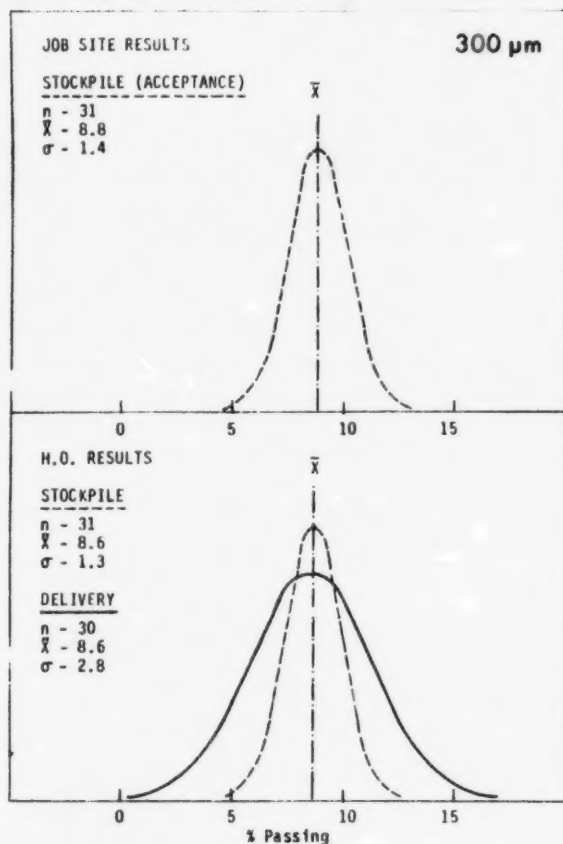


Figure 41

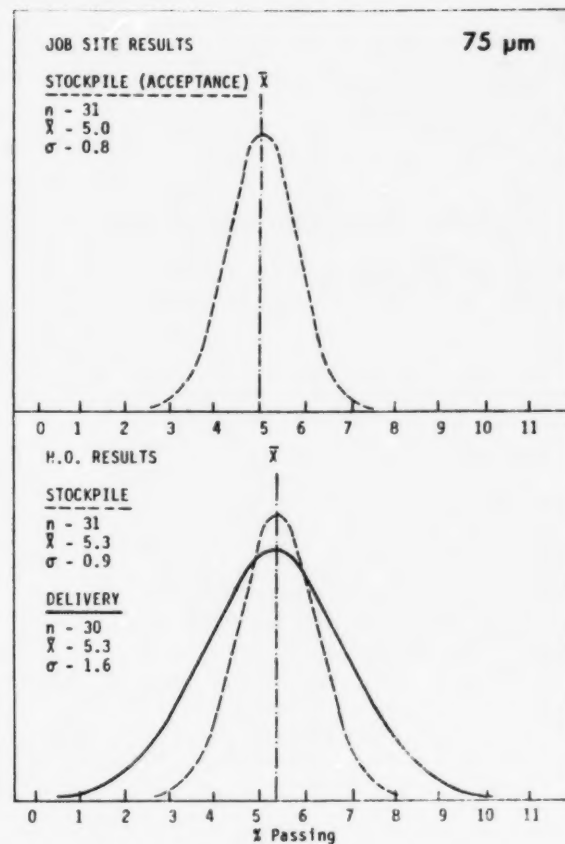


Figure 42

GRADATION SUMMARIES

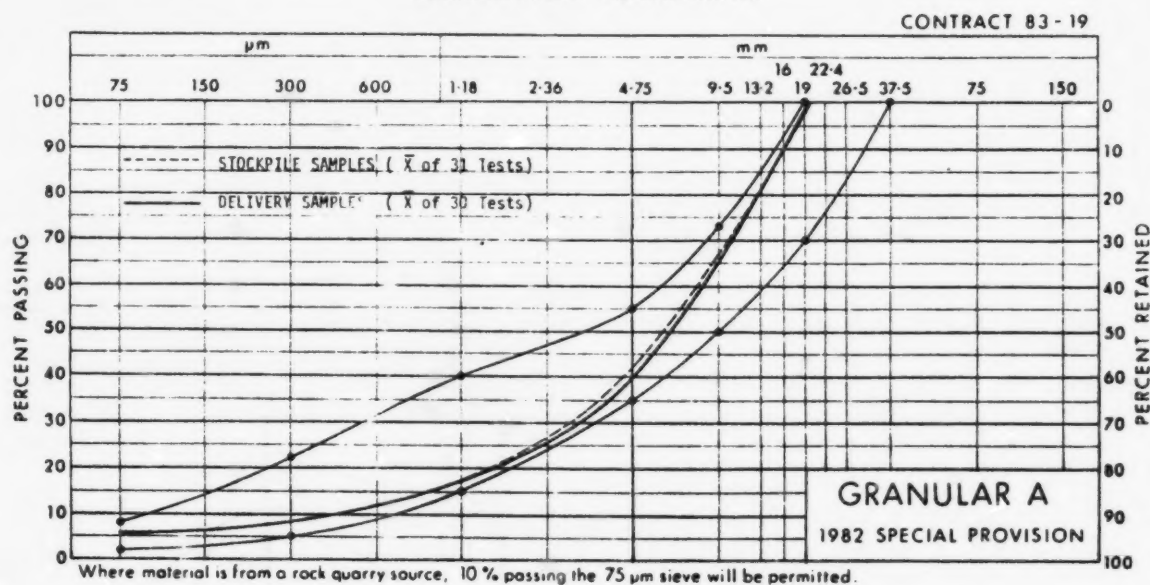


Figure 43

10. PROJECT 6: CONTRACT 83-214
HWY. 11, NORTHERN REGION

10.1 Stockpiling and Sampling

The source of the Granular A was MTC Pit 17, Granular Inventory No. T13-30. The stockpile was built by a moving stacker which dropped material a maximum of 3 m. The front-end loader then levelled the piles.

Stockpile acceptance samples were obtained on a random basis from two sides of the continuous cone created by the stacker.

Sixty samples were taken for stockpile acceptance, and 50 sample splits were obtained for testing at Downsview. Thirty delivery samples were obtained for testing at Downsview.

10.2 Analysis and Conclusions

Comparing the 50 stockpile samples against the 30 delivery samples the analysis showed that:

There was a significant difference in both the means and variances between the two sets of data on all sieves except the 19.0 mm.

The delivery samples indicated both a finer and less variable material than the stockpile samples. The results are detailed in Figures 44 to 50.

The 60 stockpile acceptance samples tested in the field were compared with the 50 stockpile sample splits tested at Downsview. The analysis showed that there was the same degree of accuracy and precision between the two testing laboratories.

11. PROJECT 7: CONTRACT 83-213
HWY. 637, NORTHERN REGION

11.1 Stockpiling and Sampling

Granular A for this project came from Pagnutti Pit, Granular Inventory No. C19-11. The stockpile was constructed with a stacker which dropped the material on the levelled area of the stockpile, while a front-end loader did the levelling. Sampling for acceptance was on a random time basis with the samples being made up of several shovelfuls from the levelled layer.

Thirty-two samples for stockpile acceptance were obtained and tested in the field laboratory, while 31 stockpile sample splits were shipped to the Downsview laboratory. The delivery samples were 32 in number, and were also tested at the Downsview laboratory.

11.2 Analysis and Conclusions

Thirty-one stockpile samples were compared to 32 delivery samples, with the result that:

There was a significant difference between the means of both sets of data.

There was no significant difference in variances on any sieve except the 300 and 75 um sieves.

The above statements show a change in gradation with the delivery samples being finer. However, no change in the degree of segregation occurred from one set of samples to the next, other than on the sieves mentioned. Figures 51 to 57 graphically illustrate the data.

The difference in results between stockpile and delivery samples was such that while the stockpile results had no tests out of specifications the delivery tests would have resulted in price adjustments to about three lots.

A comparison was made between the stockpile acceptance samples tested in the field laboratory against the split samples received at the Downsview laboratory. The results again showed that there was the same degree of accuracy and precision between the two laboratories.

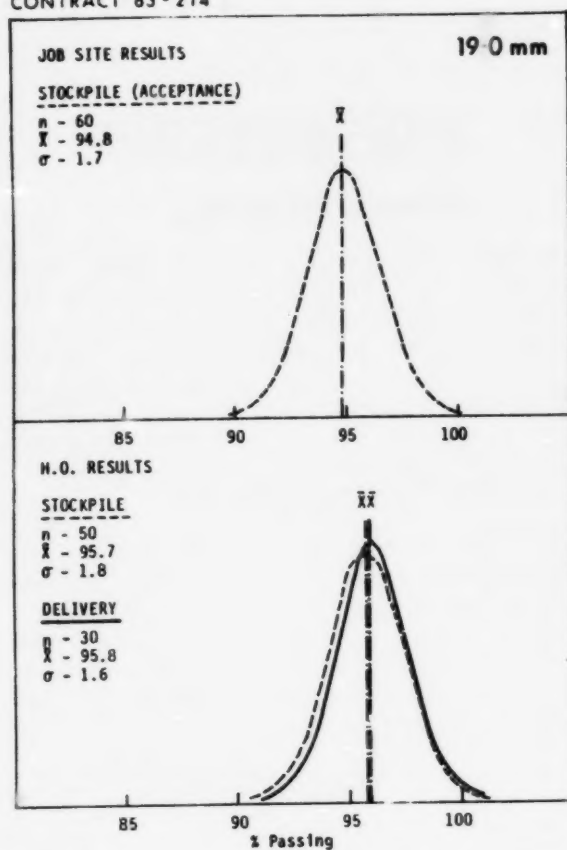


Figure 44

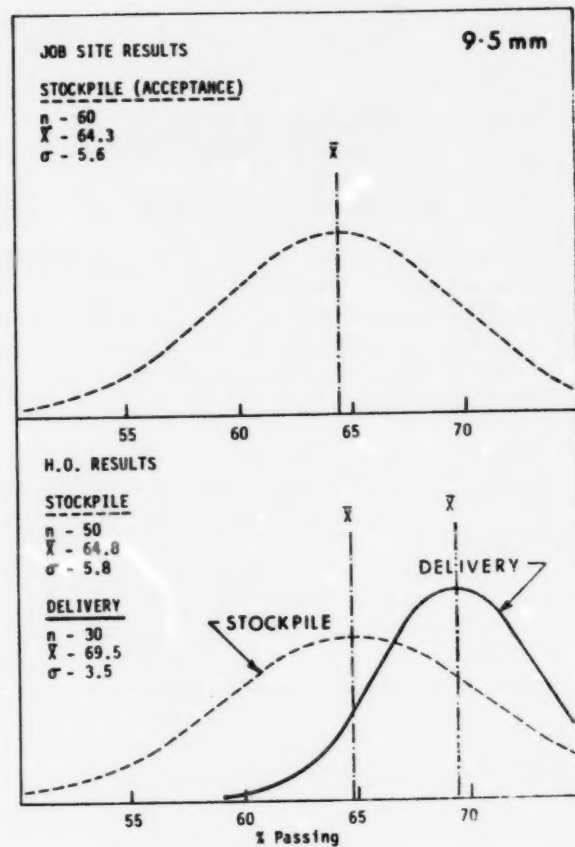


Figure 45

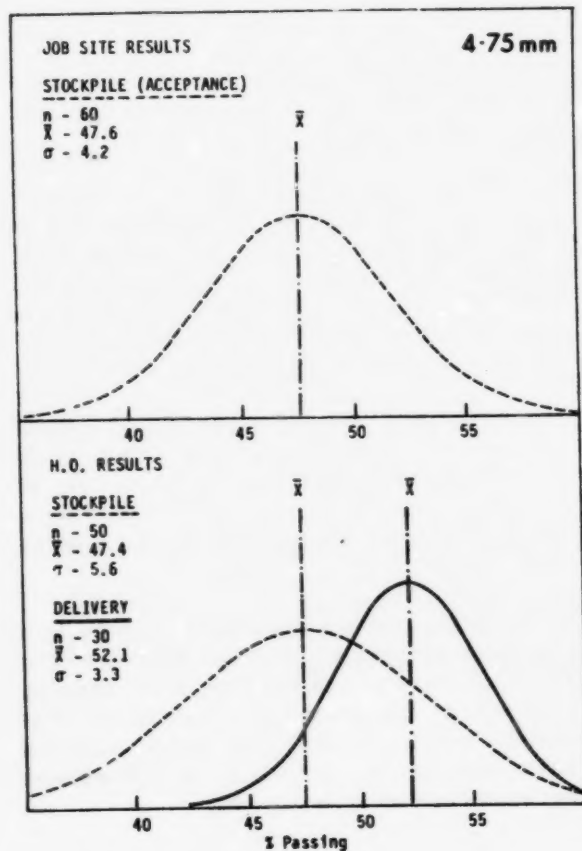


Figure 46

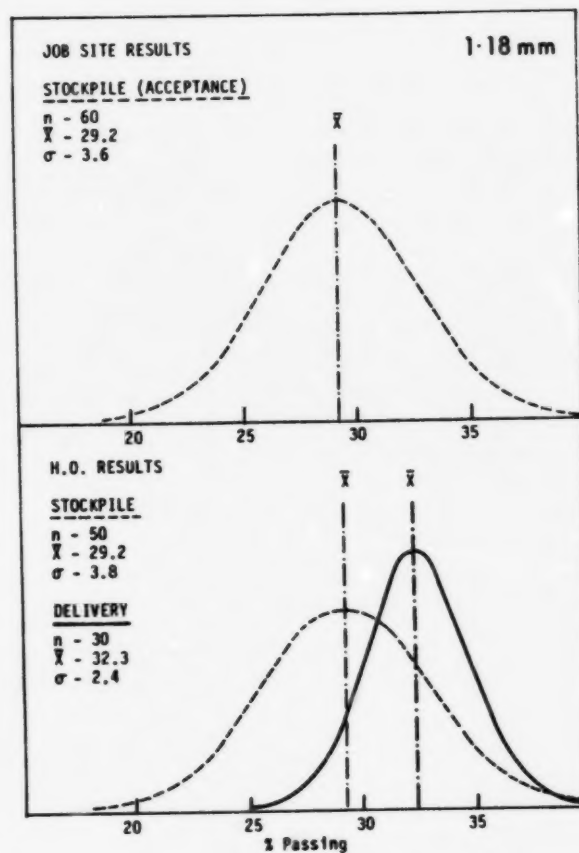


Figure 47

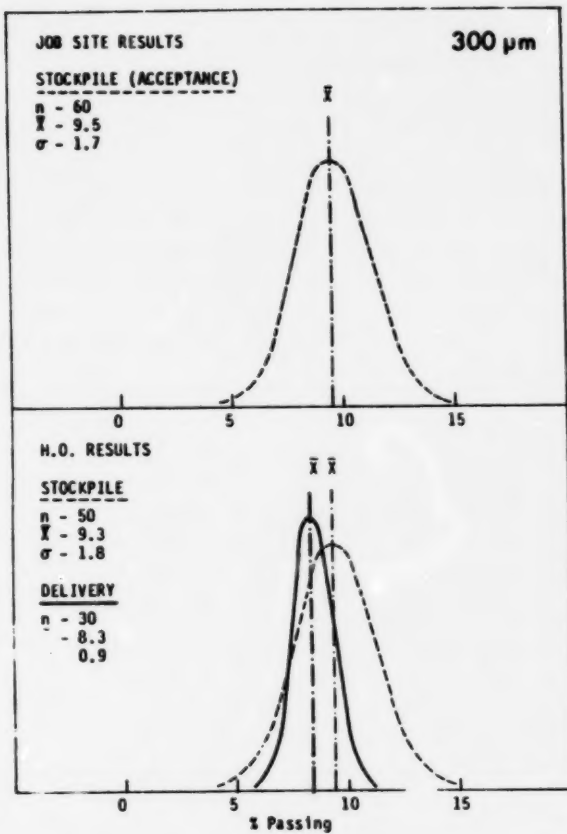


Figure 48

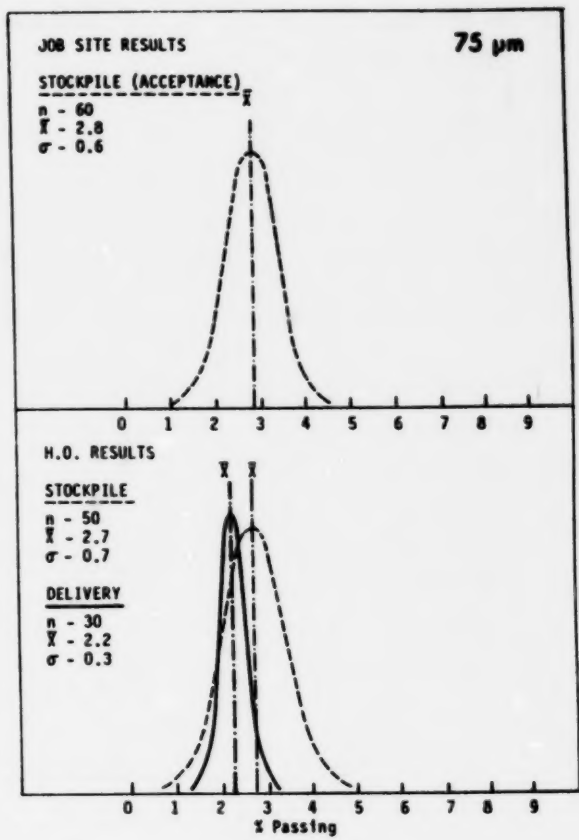


Figure 49

GRADATION SUMMARIES

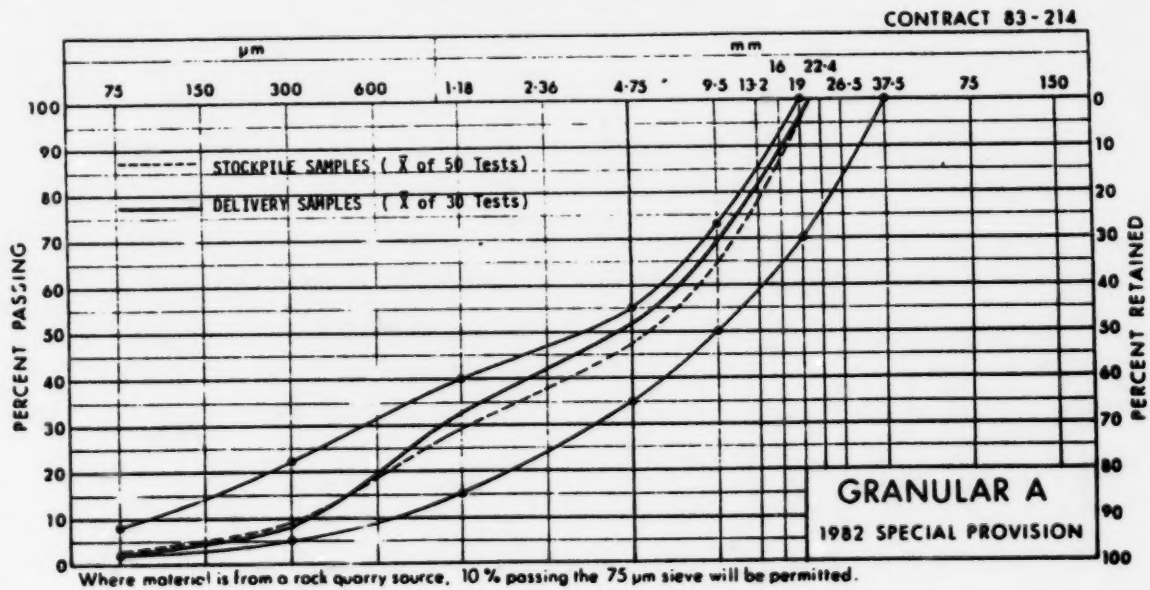


Figure 50

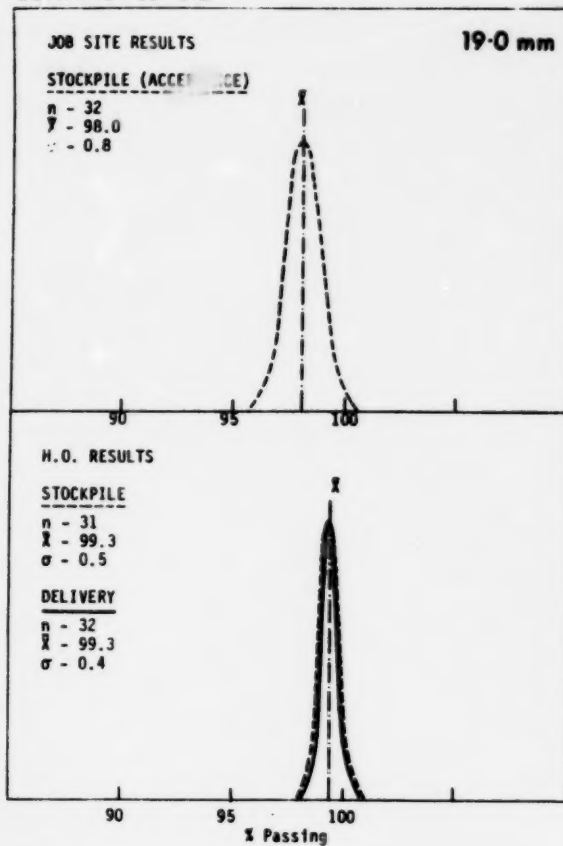


Figure 51

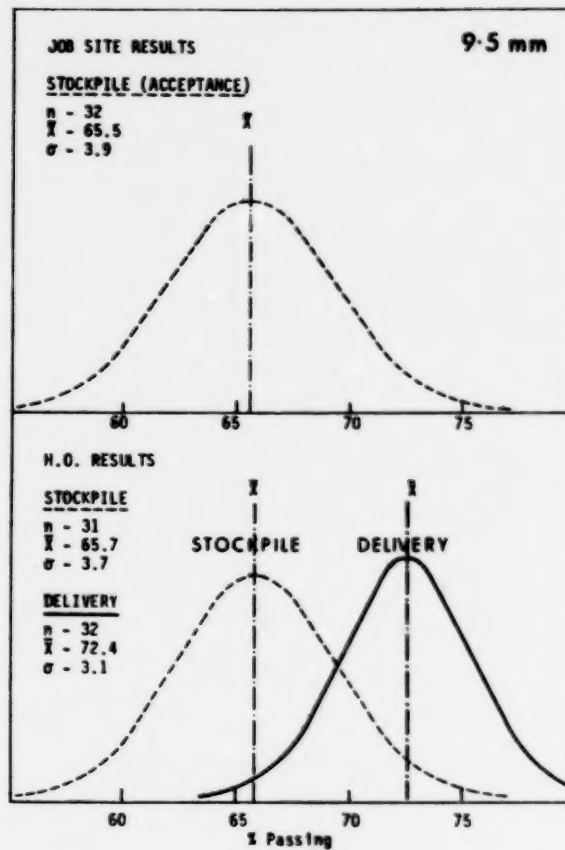


Figure 52

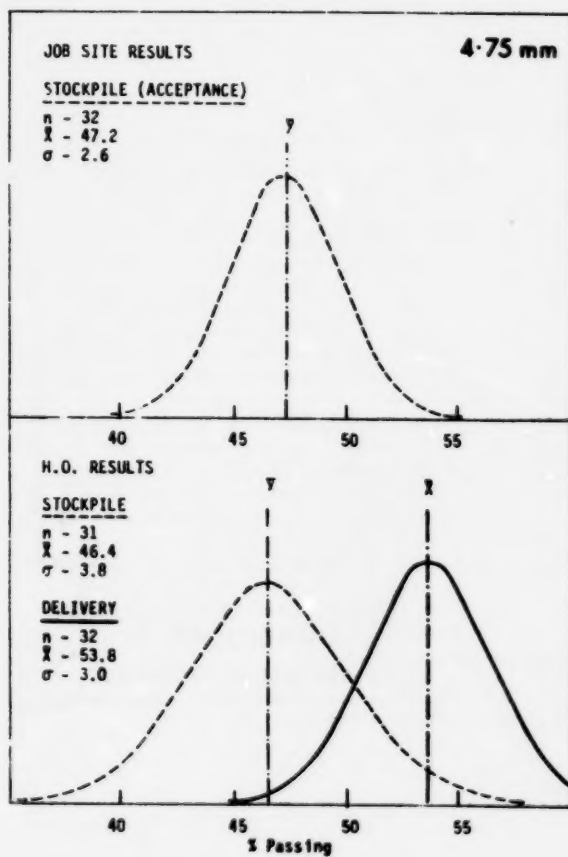


Figure 53

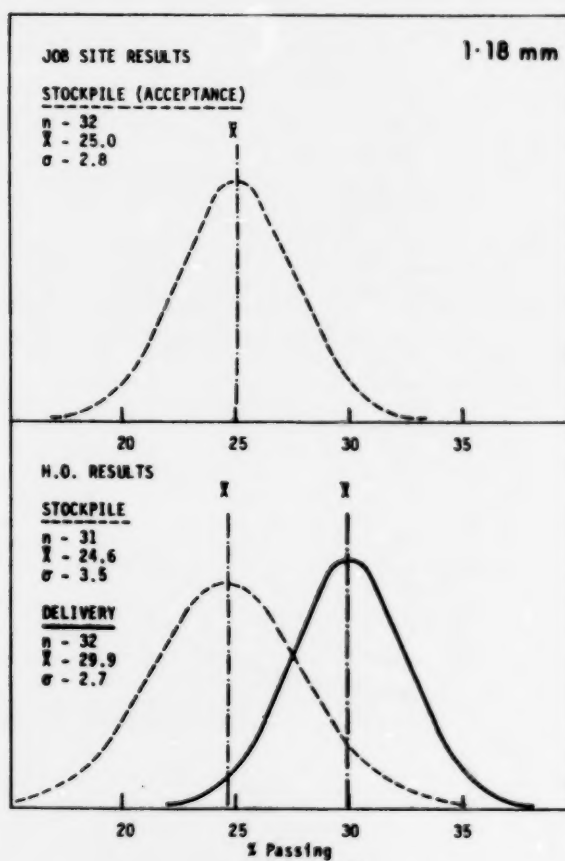


Figure 54

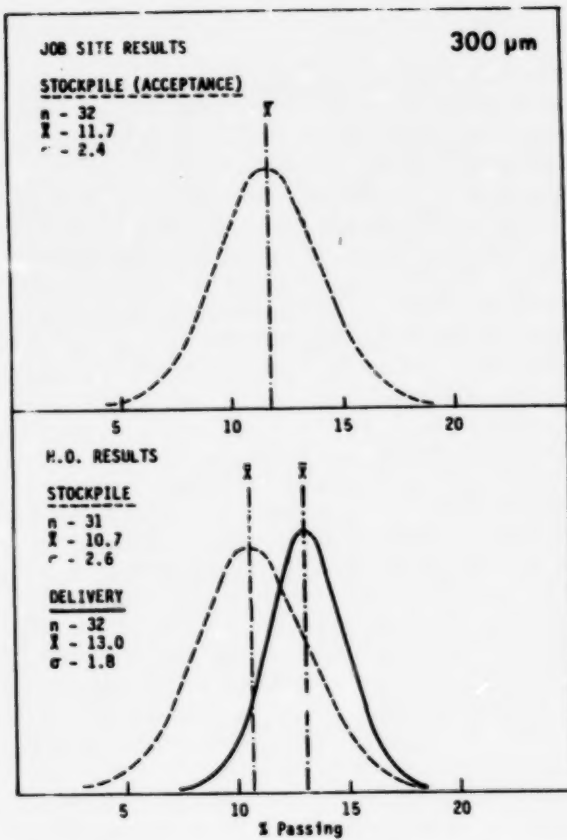


Figure 55

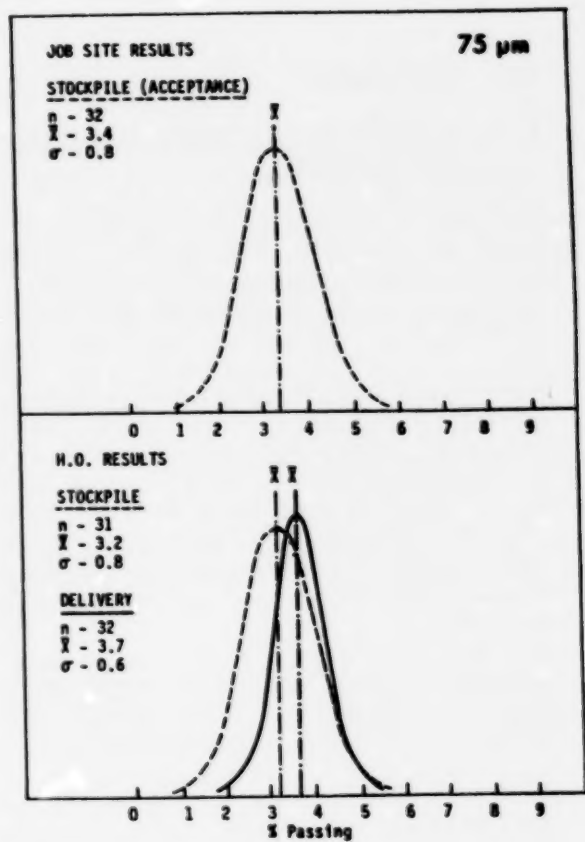


Figure 56

GRADATION SUMMARIES

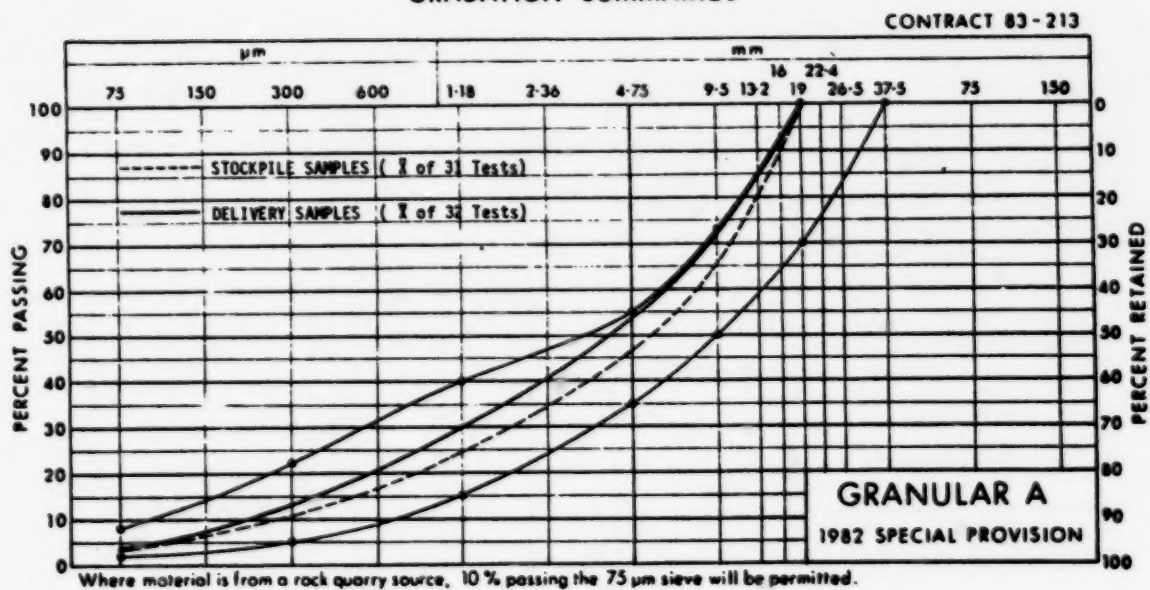


Figure 57

12. DISCUSSION

12.1 Significant Difference in Means and Variances

This report presents the findings of the study of stockpile and delivery sample results. These findings are important in setting policy for acceptance sampling of Granular A.

It was found that, in half of all the analysis carried out for means and variances, there was a significant difference between stockpile and delivery samples when both sets of samples were taken from the same stockpile. As illustrated in Figure 58 the mean of all of the delivery samples showed a finer product than the mean of all stockpile samples.

As well, in each case where there was a significant difference in the means, the delivery samples had a finer gradation.

On the average, delivery samples showed marginally less variance than stockpile samples. However, in looking at each project where there was a significant difference in variances, no trend was apparent as delivery samples had a larger variance half the time and a smaller variance the other half.

The question arises as to why there are differences in sets of samples taken from the same stockpile? The analyses demonstrated that testing is not a significant source of the disparity. That leaves sampling and the material as major sources for the differences. All samples had a high degree of randomness. There were, however, various locations and techniques used in obtaining the sample, but it is felt that, overall, the samples were representative.

As stated earlier, sampling accounts for 15 percent of the total variance in test results. Materials account for the largest portion of the variance, some 72 percent. Stockpiling can have a major influence on the variation of materials. This study showed no clear trend in variation of materials or segregation other than that delivery samples varied marginally less than stockpile samples. However, in Project 5, where there was some coning, there was a significant influence on the variation of delivery samples as caused by improper stockpiling procedures. It is obviously very important to follow accepted stockpiling methods. Although the limited number of projects studied did not prove that stockpiling methods are the major source of variation, the evidence is strong that they are a serious contributing factor.

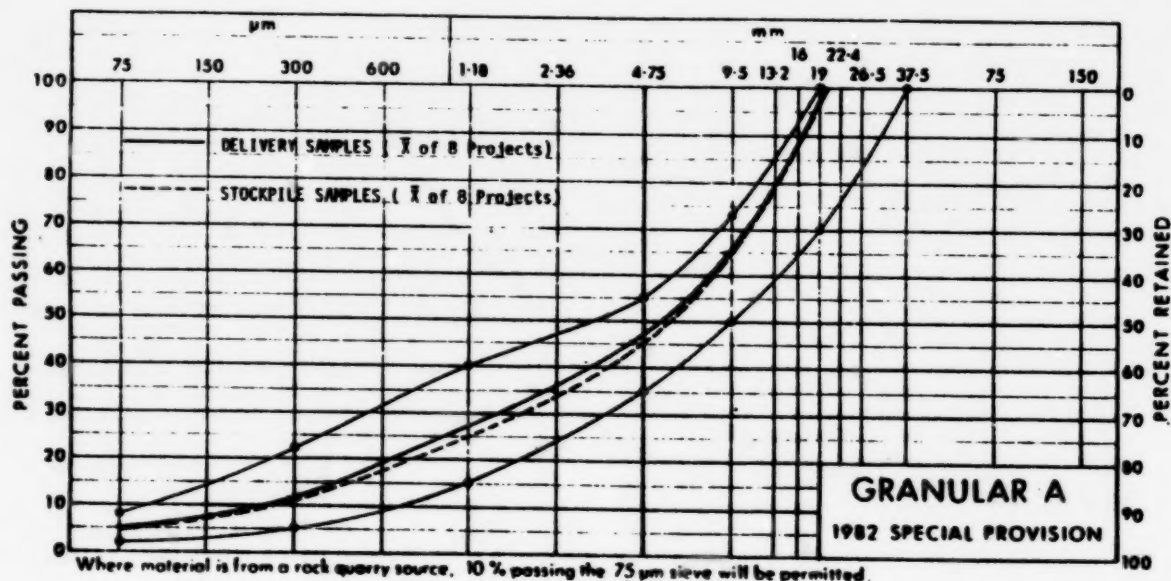


Figure 58

12.2 Stockpile Sampling

With the intended move in 1983 to road sampling it appears that stockpile sampling became a forgotten stepchild, as evidenced by the wide variety of methods with which it was carried out. In a couple of projects the material to be sampled for acceptance was thoroughly mixed prior to stockpile sampling. This sample then does not represent the material, as it actually is in the stockpile, but simply represents the material's ability to meet specifications following mixing. None of the previous or following loads of material received this treatment. This same argument applies if material is sampled on the pit floor rather than in stockpile as any handling can change the gradation.

On a number of contracts, the actual sample was taken using shovelfuls from over the entire layer. This, we believe, has a potential for bias as the technician is making the decision from where to obtain each shovelful, rather than being controlled by a random number.

The following stockpile sampling principles are recommended:

- a) Samples for acceptance should be taken from the levelled portion of the stockpile after all processing by the contractor is finished.
- b) The sample should be obtained from one spot only, rather than filling the bag from several locations.
- c) The sample location must be randomly determined to ensure that it is representative of the subplot.
- d) A procedure should be set up to ensure that visually out-of-specification material is not incorporated into the stockpile.

12.3 Stockpiling

During the study, a variety of ways of building a stockpile using the layered method was observed. This, in itself, is not a problem, however, major deviations from the accepted procedures increase the likelihood of segregation occurring. NCHRP Report 46 states that "segregation is minimized when stockpiles are formed by spreading the aggregate in thin layers, and reclaiming with a front-end loader". It also states that, "for any condition of high segregation to be corrected, the aggregate must be spread in thin layers over a relatively wide area of the pile". It continues with the obvious; "the largest amount of segregation was found in all types of coned or tent shaped piles, regardless of aggregate type or gradation."

Based on the above, and the findings of this study, it is recommended that stockpile construction closely follow the requirements of MTC specifications. Otherwise there can be no confidence that stockpile samples are representative of the material received on the road. If, for any reason, proper stockpiling procedures are not followed, then samples for acceptance must be taken either during delivery or from the road.

12.4 Field Laboratories

The stockpile acceptance samples taken by the field technicians were split, with one half tested in the on-site field laboratory for acceptance, and the other half tested in the Downsview laboratory. Any differences in results would, therefore, be due to the normal variation of the material, testing procedures or equipment. Statistical analyses showed that there were no significant differences between the means or variances for any of the sets of samples, other than for Project 3, indicating overall, an excellent degree of precision and accuracy between our field and Downsview laboratories.

13. CONCLUSIONS and OBSERVATIONS

a) Where there was a significant difference in mean gradation between stockpile and delivery samples, delivery samples were finer.

b) Where there was a significant difference in variances between stockpile and delivery samples no trend was apparent. Delivery samples varied more, half the time, and varied less the other half.

c) Field laboratory results showed no significant difference in mean or variance from the Downsview laboratory results, except for Project 3, where the fine gradation mean was significantly different.

d) There was a variety of ways of building a stockpile using the layer method.

e) The MTC used a wide variety of locations and methods to obtain a sample for stockpile acceptance.

f) There was some bias shown by MTC staff in obtaining a stockpile sample.

14. RECOMMENDATIONS

a) If the contractor chooses to follow the requirements of subsection 1000.09.05 of MTC Form 1000 in building a stockpile, then samples for acceptances could be taken from the stockpile under conditions outlined below. Otherwise, acceptance samples must be taken during delivery or from the road.

b) The method of stockpile sampling should be uniform across the province.

c) If an acceptance sample is to be taken from the stockpile it must come from a levelled area.

d) The random method in determining the location for a sample should be followed.

e) The sample should be obtained from one spot, rather than from several locations across a subplot.

15. ACKNOWLEDGEMENTS

The Ministry wishes to acknowledge its appreciation to all contractors and suppliers, involved in this study, whose co-operation ensured its success. The authors wish to extend appreciation to all staff in the Downsview laboratory and all field technicians, project supervisors and quality assurance officers for their helpfull participation. We would also like to acknowledge the diligent efforts of Mr. I. Bullen, Mr. F. Bacchus, and Mr. H. Pankratz. Mrs. J. O'Brien's typing of this report is also appreciated and acknowledged.

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